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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, December 19, 1900.

A DISCUSSION OF RECENT DEVELOPMENTS IN THE FIREPROOFING OF WOOD.

BY JOSEPH L. FERRELL, M.E.

I have the honor to present in this paper a simple statement of ascertained facts, susceptible of easy and prompt verification, and offer no theories whatever in the subject under consideration.

Whether it is valuable to render wood an obstacle to flame, rather than a contributor to it, can hardly be considered as a serious proposition; evidence as to the practical doing of the thing is here before us.

The methods of doing it, the tools with which it is done, the efficacy of treatment, are the subjects of this paper.

Up to seven years ago the history of this art was a series of sporadic attempts to impregnate boards and timbers by

impracticable processes and apparatus, with impossible chemical solutions; and the best evidence of their worthlessness is their failure.

In the United States Patent Office over 400 patents have been issued since 1790. These are all chiefly interesting from the impossibility, inherent in their nature, of practical operation.

Much ingenuity had been shown in devising apparatus and processes for the impregnation of wood with preservative substances, and the best form of such apparatus has recently been adopted by those who have made the com-

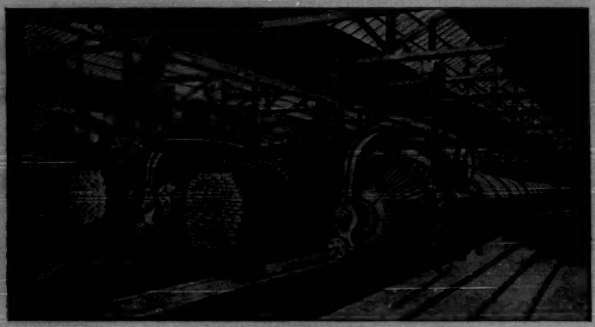


FIG. 1.—Old type of cylinder, showing complicated and cumbersome external end-gate.

mercial initiative in fireproofing wood. In fact, the actual apparatus, identical in almost every feature, used by the first company to fireproof wood for private and governmental uses, was for some time used to treat wood with preservative solutions.

The old apparatus is in general similar to that shown in accompanying engraving. It consists of a cylinder of about 84 inches diameter, built up of steel or iron plate, in some cases 100 feet long, with a door at the front end swung upon hinges and fastened with a multilocking system of bolts. On the bottom of the cylinder is a track upon which

the cars loaded with lumber rest. The cars are run in through this door, and when the treatment is over are backed out again and sent to the dry-kiln.

To saturate wood the lumber is placed in the cylinder, the door closed and fastened, steam is admitted, and the wood subjected for hours to its action. The purpose claimed is the softening of the mass and the saps contained therein.

This operation is followed by a vacuum which aims to extract the liquefied saps, so far as practicable, and this process also occupies many hours. Subsequently the vaporized mineral salt was admitted to the softened wood (this part of the process is now discontinued), and finally the

FIGS. 2 and 3.—Details of old type end-gate.

liquor was run into the cylinder, completely filling it, after which a powerful pressure pump was set in motion and pumped additional liquor into the cylinder, thereby raising the pressure therein.

This operation also occupied a long time, the whole series of operations requiring from 20 to 35 hours, according to the kind and thickness of the wood under treatment.

As the first movement to achieve a practical result, this was a very creditable one. As a complete, practical and logical system, it proved a complete failure.

The old systems are based upon fallacies:

(1) Steam in contact with all woods destroys the fiber, and seriously affects its color.

(2) In so far as steam does soften the wood, so does the subsequent vacuum act upon the softened fiber and seriously distorts it.

(3) The most serious result is the loss of the liquefied saps and substances contained in the wood, which are as valuable to the wood, as wood, as the fiber itself, and if it were possible for the vacuum actually to suck out all the liquefied saps, the remaining fiber would have no cohesion and would be a friable, spongy mass of useless material.

The fact that the vacuum can only get at the saps of the surfaces or near to the surfaces is the salvation of the wood treated in this way, and, in a great measure, the objection in the case of decks of ships and other places where the surfaces of wood thus treated are exposed to wear, that it roughens up and rubs off, is due to the fact that the cohesion of fiber is disturbed, and that there is no natural substance left with which, at least in a degree, the impregnating chemical may unite in forming a new insoluble substance in the superficial wood cells, consequently the chemical lies in crevices instead of being incorporated with the fiber, and readily washes out and is displaced.

Referring to a report made by experts of the U. S. Navy Department as to fireproofed woods submitted by the two companies now in operation, which report is dated November 27, 1900, the following passage occurs: "The tests have already progressed sufficiently to show that the ultimate values of the woods treated by the two processes are very nearly equal, yet in both the products are imperfect in that they do not remain permanently impregnated with their fireproofing compounds under certain circumstances encountered on navy vessels."

It is difficult to understand how this loss can occur, if the compounds are the phosphates and sulphates of ammonia, except for the reasons before alluded to, that the treatment measurably evolves the albuminous substances and other sap products from the surfaces and layers near the surfaces, thus obviating any practical chemical union around the individual fibers.

Henry Valentine Simpson, Lieutenant R. N. (England),

who for a long time managed the practical part of the business for the London Non-Flammable Wood Company, Limited, of London, England, writes under date December 5, 1900: "Our climate is certainly against this process; the wood sweats in damp weather, drawing the salts to the surface. I am certainly deeply interested in this industry practically * * * * and, next to yourself, believe I know as much about it as any one."

Lieutenant Simpson has patented other chemical solutions, which he believes will achieve the location of an insoluble product in the wood. From his acute intelligence and from his long practical familiarity with the old operative machines, he is to-day probably the best trained expert in the world working on the old lines of apparatus and processes. It seems now to be an established fact that successfully fireproofed wood must have the chemical fixed in the wood immutably, so that no atmospheric or other effects can possibly disturb it.

Investigators are gradually coming to a definite agreement on this point, and the general subject is attracting the most serious attention of disinterested scientists all over the world.

The *Journal of the Society of Chemical Industry* (London) contains, in its issue of December 30, 1899, a paper presented by Sherard Cowper-Coles, which, with the record of the accompanying discussion by eminent members of the society, affords a clear view of the situation as regards the then known status of the art.

"A number of tests by Drude tend to prove that steaming wood before impregnating tends to lessen its absorptive powers. Simpson has found that oak, if exposed long to the action of steam at a high temperature, is very apt to warp or crack; soft woods, such as deal, pine, ash and the like, are apt to become discolored under the same conditions.

"Dr. O. J. Steinhart, of the Society, in course of the discussion, asked whether phosphate of ammonia was the fireproofing material employed by Simpson. He stated that phosphate of ammonia gave rise to a fungoid growth which might rot wood. He also would like to know what was the

corrosive action of phosphate of ammonia on metallic parts. He considered that important, as, if phosphate of ammonia were used, iron parts might come into contact with the impregnated wood in ships, etc. He had always understood that phosphate of ammonia did affect ironwork.

"Mr. Sayer said that woods impregnated with salts of ammonia were unsatisfactory."

These are the judgments of acute observers, which confirm the results of practical commercial tests.

After all, there is no method of arriving at final and conclusive results so perfect as by the patient development of simple apparatus for impregnation, which will do the plain work beneficently and rapidly on the large practical scale, and (knowing by long experience, and experience only, the injurious effects of the old chemical formulæ) to devise new formulæ free from the detrimental qualities complained of by those who have used the products already given to the public.

The chemical problem is now the most serious one, not wholly because of the great difficulty in laying hold of a formula which will respond to the requirements for use, but in getting a formula the cost of which shall be no obstacle to making the fireproofing of wood of universal applicability.

The apparatus which will thoroughly saturate wood with preservative solutions will, of course, equally perform the function of saturation with fireproofing solution.

The old forms have become obsolete, because a more complete, practical study has disclosed their errors and weak points, and their superfluous complications, all of which means cost and expensive operation.

Development in this direction proceeds logically and from inherent necessity, just as in every other phase of human progress. Take the form of pumping engines of only half a century ago and compare them with those in common use to-day!

The subject of saturation is as yet scarcely touched. If what we are doing affords promise of universal application because of the good results obtained, and wood can be preserved and fireproofed cheaply and beneficently, a new

industry will surely be created, of vast proportions. Chemical science may reasonably be expected to develop ingenious, cheap and thoroughly efficacious formulæ; whence it may come to pass that wood will be made immune from fire and decay at a merely nominal cost. All we expect to accomplish is to advance the art a step.

It is not easy to understand how the mechanical features of saturation can be more simplified than in the new cylinder machine. The operation is so effective and direct that, were it not for the subsequent drying, boards and thin planks could almost be saturated with the chemical whilst the lumber wagons waited for them, instead of occupying days for the cumbrous and complicated old system to perform the same function. The elimination of the useless and very injurious preliminary processes of long steaming and subsequent suction means an enormous saving of time, and avoidance of harm to the wood under treatment.

It must be considered, however, that, independently of the objects claimed for the steaming and vacuum, a decided advantage accrues to the users of this process, in that the wood is rendered open and soft, so that a comparatively light pressure on the liquor in the cylinder, in the last operation, suffices to penetrate, where it would not otherwise reach.

Now, the pressures employed must necessarily be light for two reasons:

(1) The cylinder itself will not endure a heavy pressure, nor will the gate, being exteriorly attached, keep tight; and, when leakage occurs, pressure drops.

(2) The pressure, being applied directly by a pressure pump, must be deftly manipulated to prevent the water-hammer from utterly destroying the softened fiber; therefore, for this reason rapid operation or high pressure is out of the question. The saturation, therefore, by this process must occupy a seriously long time, and the wood must necessarily suffer more or less injury. The pressures being light renders it impossible to saturate to the heart any dense wood, or any great thicknesses of soft or light wood. The great length of time is absolutely prohibitive of cheap

treatment. The enormous cost of the principal and least objectionable chemical also bars the way.

Pure phosphate of ammonia, which can be bought at the present time for 9 cents per pound, means for a 130 per cent. saturation of white pine, with a 20° Beaumé solution, a cost of $71.79 per thousand feet for the chemical alone, although, after exhaustive investigation, we believe it can be manufactured in this country for about 5 cents per pound, in which case the cost of the chemical would be $39.89 per thousand feet. Therefore, to do business a resort must be had to a cheaper element, which has distinct and serious disadvantages. Even at the best, by the use of other chemicals, the cost of chemical alone ranges about $25 per thousand.

Of course this is all impossible. Unless the wood can be treated rapidly and beneficently with a cheap chemical without a single detrimental quality, and on the whole strengthened and bettered in other ways than the fireproofing, fireproof wood cannot reach the public.

To accomplish this result, years of unremitting labor have been applied. Instead of the old haphazard, empirical methods, a clearly defined, scientific study has been followed along scientific lines.

First, taking the art in the phases known, examinations were made of the most thorough character into the nature of all the principal commercial woods, and the methods previously employed were reproduced in long series of tests, to ascertain effects of the different elements of the old processes, and their respective values.

The results of these tests proved conclusively that—

(1) Steaming is radically wrong in principle.

(2) Suction is in the highest degree injurious.

(3) Direct application of reciprocating pressure, especially to wood subjected previously to the above treatment, is destructive.

These determinations, therefore, compelled the abandonment of the mechanical features and processes of application which had previously been employed.

Granting, however, that the old mechanical methods and

processes were beneficent and scientific, and that the wood could be uniformly and perfectly saturated with a chemical absolutely unexceptionable for the effects intended, it yet remains a fact that the *time factor* alone would render the whole system impracticable for universal use. On this point, it is sufficient to say that the old method demands from twenty-five to thirty-five hours to produce requisite saturation of thin sections of wood.

If, added to this impracticable feature, we have a chemical solution, the best by general consent then discovered, costing at the very least $25 per thousand feet board mea-

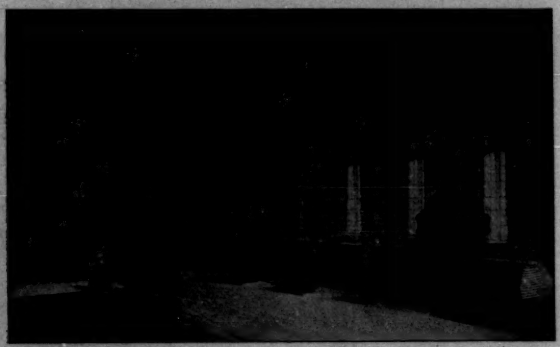


FIG. 4.—Cylinder used in new process, showing internally seated end-gate.

sure, the impossibility of any practical solution of the problem must be obvious at a glance. For, no matter how perfect the fireproofing effect, how permanent, how beneficent to the wood treated, if the total cost is excessive, it becomes prohibitive.

It became necessary to revolutionize the entire treatment of the subject.

Instead of the application of low pressures and long time, the employment of high pressures and short time of saturation was tried.

Steaming was at once discarded; vacuum also.

The wood, therefore, being in its normal condition, was treated directly with the solution under pressures from 50 to 1,200 pounds, and results carefully noted.

Every thickness up to 10 inches square, of sixteen different kinds of wood, was thus treated, and treated each in long series.

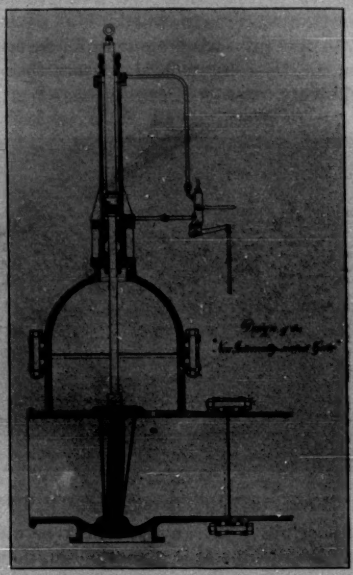


FIG. 5.—Details of new internal end-gate.

It was discovered that each thickness of each wood had its exponent of resistance to compression, but the greater pressures were apt to overcompress and distort the wood. To obviate this, the hydraulic accumulator was interposed, which at once and most satisfactorily obviated all welting and distorting, and by the maintaining uniformity of pressure, instead of reciprocating application, produced much more rapid saturation.

All this preliminary study was done with a small apparatus, and it became necessary, for practical purposes, to know what could be done in an apparatus of commercial size.

At once the problem arose as to the type of gate for the cylinder. The old forms, as a matter of course, could not endure the enormous pressures it became necessary to use in working out this principle, nor could the old plate cylinders of large commercial size endure such pressures.

Therefore, steel castings were adopted for cylinders, competent, in the first small commercial test plant, to stand a pressure of 1,500 pounds to the square inch, and the gate devised was an internal disc, rising vertically, lifted by accumulator pressure, seated outwardly and pressed to the seat by the pressure of saturation.

A cylinder 12 feet long was therefore made, 18 inches diameter, attached to a massive gate body. In this cylinder, for twenty months, every size of every commercial wood has been rigorously tested and the result most carefully tabulated.

White pine boards, under a pressure of 300 pounds per square inch, are saturated to from 120 to 140 per cent. in half an hour, as against about 90 per cent. by the old system in thirty hours.

The problem of healthful saturation of all woods by high pressures by external compressional applications is finally and correctly determined.

Concurrently with the mechanical studies ran of necessity the chemical study. Its importance is vital, as it is the most serious element in the whole matter.

Wood, at the beginning of this investigation, had never been known to the world to be perfectly saturated to an ample degree with any solution, which was wholly harmless to the wood, to produce immunity from flame.

This is a broad general statement, and of course is only meant to affirm that such was the case as to general knowledge.

The Russian chemist, Peter Lochtin, who made a most crucial investigation into this subject some years since, tested nearly a hundred substances and finally sifted them

FIG. 6.—Before applying the torch. Test of fireproofed wood made at the yards of the New York Shipbuilding Co., Camden, N. J., June 19, 1900. Two small buildings were erected similarly constructed, one built of ordinary wood and the other of wood fireproofed by the Ferrell process.

FIG. 7.—After burning eight minutes.

all down to a possible three or four, first among which was phosphate of ammonia, and second, sulphate of ammonia. He gives the relative values of all the others and the reasons why they do not respond to the final tests of utility.

Phosphate of ammonia, of all substances known at the beginning of this investigation, was the most promising. Wood, perfectly saturated with it to the heart, resisted the fiercest flame more effectively than any other solution, but its cost is prohibitive. In a pound of the chemical, the cost of the ammonia requisite is alone beyond the cost permissible of a pound of the chemical which can be used for this purpose, and make it a practicable thing, leaving out the cost of the necessary sulphuric acid, however produced, with the other accessory costs of production.

Even were it cheap enough to be used, work enough has been done to determine beyond question that, whilst it is the least harmless to the wood of all the long line of solutions, it still does have an effect to render the fiber brittle, and this seems impossible to counteract.

Sulphate of ammonia comes next in value, a stronger solution, however, being necessary to produce an equal fireproofing result.

But the difficulties of the phosphate are accentuated in the sulphate. Wood loses its brightness of color, its flexibility of fiber, and it shows a more hygroscopic tendency.

Both the phosphate and sulphate corrode metals. The sulphate, from its relative cheapness, and from its excellence of fireproofing, is a most attractive chemical, and therefore is more used than anything else. This corrosive action has been the cause of the complaints of the English Government as to the work done by the London Company on the Queen's yacht and several vessels of the Admiralty, and for the United States Government on many vessels of war, which have been the subject of much unfavorable criticism, and have dampened the interest of the public generally in the subject of fireproof wood.

Where these chemicals are used separately or in combination the results complained of will infallibly occur. Even if the sulphate of ammonia could be rendered harmless, it

FIG. 8.—After burning fourteen minutes.

FIG. 9.—After burning sixteen minutes. House built of ordinary wood completely destroyed.

could only be done at an addition to its present cost of 3 cents per pound, and that cost alone is prohibitive to its broad use. Therefore it has been compulsory to traverse a wholly new ground, not even trodden by the distinguished Russian chemist.

Years of incessant and laborious practical investigation have been devoted to this side of the question, and the result has been a marked advance upon the previous history of the chemical side of the fireproofing question.

Two formulæ have been discovered and tested finally as to their perfectness for this use. By their employment the chemical cost will be reduced to less than one-third of what it has ever before been, and when the wood is saturated with the solution, it is wholly free from the faults hitherto complained of.

It maintains its original color and freshness. It will not corrode metals in contact. It will not attract moisture. It will not brittleize the fiber. It will never volatilize by time. It will take paint and varnish and retain them.

This chemical result, with its perfection and low cost, combined with the low cost and short time of mechanical treatment, makes the universal use of fireproofed wood quite practicable.

In treating sawn lumber in the liquid bath, each kind of lumber and each thickness of that kind has its own peculiar coëfficient of normal pressure at which it will become impregnated with the greatest rapidity.

If we exceed this, the pressure compacts the fibrous mass, and prevents the rapid saturation, filling the superficial layers with an excess of solution and preventing the proper amount from reaching the heart. Thus, it may happen that there is a great excess of the chemical, when dried, over what is necessary to perform effectually the functions of fireproofing the whole mass; yet a half inch under the surface the solution has not penetrated. This cannot occur if the ascertained conditions of saturation are obeyed, by which an even distribution of the solution is located throughout the mass. In larger sections, say from 6 inches by 8 inches and upwards, and particularly in the denser woods, this is more likely to occur.

The long time, relatively, it required to treat all larger sections in the correct way, that is, evenly throughout, to the heart, suggested a new departure in investigation, which has been successfully carried out in a marked degree.

This development may be termed the expressive, in contradistinction with the other, which we will call the compressive treatment.

In one sense the expressive idea is not new, any more than the compressive, only the means employed and the employment of the means radically vary from anything which can be found on record, after long and exhaustive search.

One apparatus has been doing practical work on saturation of logs, running from 14 inches diameter up to 27 inches diameter, and 9 feet long. The apparatus is open, and the pressures of liquid are applied to the end centers. It makes no difference whether the logs or timbers are small or large in section or diameter, or of what length.

This machine necessarily must be constructed in three different forms to meet the peculiar conditions encountered in practice from varying structure of trees.

It is not practicable as yet to give the minute details of this process and apparatus, inasmuch as the patents are not sufficiently advanced to enable it to be done, but it is entirely true that timbers and logs of all commercial woods have been saturated in an incredibly short time, from center to periphery, every fiber having been enveloped in the saturating solution.

For instance, the section of holly log before us was part of a log averaging 17 inches diameter and 9 feet long. Of course it is known how dense a wood holly is. A holly log like this could not be equally saturated in the compressive system in the cylinder in a month, perhaps never, the wood being so dense and the necessary pressure in that system being so great, constriction of the fibrous mass would be so powerful that nothing but superficial saturation could take place.

In all great centers of population, where structural work is done on enormous scale, the buildings are supplied with

dimension lumber by the lumber yards. This is the source of supply from which all the boards, planks and small timbers will come to be fireproofed, when the necessity for that to be done is fully recognized, and when it is as thoroughly understood that fireproofing wood is an honest, every-day matter of business, and it can be done uniformly at a very low cost.

The internal compressive system of apparatus will do the work perfectly, quickly and cheaply on all woods up to 6 x 8 inches and on soft woods up to 12 x 12 inches. Above these dimensions, to any section or any length, the expressive apparatus will thoroughly operate at no greater cost per thousand feet board measure than is required to treat 1-inch boards by the other system. No matter whether the wood be white or yellow pine, oak, ash, poplar, beech, birch or any wood cut from a tree, it acts equally well and equally cheaply.

It will thus be seen that the apparatus termed the expressive is the supplement of the internal compressive type; and both together comprise a system of practical operative machines which effectively covers the whole ground of saturation.

The invitation so kindly tendered by the Institute to present the actual facts as to these discoveries is most heartily welcomed.

That the matter is interesting to the professional minds of this body is a source of the sincerest gratification.

THE PARIS EXPOSITION, 1900.

SOME NOTABLE ELECTRICAL ITEMS.

By Dr. A. E. Kennelly,
Delegate of the Institute.

The International Electrical Congress of 1900 at Paris was well attended. Seven hundred and sixty members were enrolled, and eighty-three official delegates from the various governments. The congress met on the 18th of August, at Congress Hall, in the exposition grounds, and held its later

sessions (closing the 25th of August) at 44 Rue de Rennes. A number of interesting papers were read. The congress adopted names for two electro-magnetic units in the centimeter-gram-second electro-magnetic system; namely, the "maxwell" as the C.G.S. unit of magnetic flux, corresponding to what has frequently been called a "line" in the past; and the "gauss" as the C.G.S. unit of magnetic intensity, or flux density, corresponding to one maxwell per normal square centimeter.

Among practical electrical features of the exposition, one of the most interesting and successful was the moving sidewalk, which formed an endless belt within the interior contour of the exposition lines of buildings. It had a length of 3,400 meters. It consisted of one stationary platform 1·6 meters wide, next to it a moving platform 0·90 meter wide, travelling at about 2½ miles per hour, and next beyond this a moving platform 2 meters wide travelling at double speed or about 5 miles per hour. All three platforms were situated at an elevation of about 7 meters above the ground. The moving sidewalks were driven by 172 5 horse-power direct-current 500-volt series iron-clad motors. The motors were intended to be operated in parallel, but sufficient speed was obtained when they were connected in parallel arrangement of two in series. The weight of the high-speed platform was about 1,000 metric tons, and of the small platform 700 metric tons, making the total weight moved 1,700 metric tons, without passengers. As many as 15,000 persons are estimated to have been carried at one time on the platform. The motors were uniformly distributed along the route and were stationary, one side being mounted on a fixed axis and the other pressed upward by a spring so as to engage the motor pulley with the lower surface of an I-beam in the base of each platform. The motors seem to have operated with entire satisfaction throughout. The starting direct current supplied to the motors was about three times the current required for their normal operation. About 230 kilowatts is stated to have been expended at the sub-station generator for the operation of this platform when empty, and this increased

to about 330 kilowatts at maximum load, or about 260 kilowatts under ordinary normal load. The sidewalk was usually in operation between the hours of 10 A.M. and 7 P.M. The direct current was generated by a 600-kilowatt Westinghouse generator coupled directly to an 850 horse-power multiphase induction motor supplied through transformers from 5,000-volt mains leading to the power house at Issy-le-Moulineaux.

The sidewalk was very popular and effective. It has shown that where sufficient space can be obtained, large crowds can be successfully carried at low speeds to a limited distance at a low expenditure of power per individual. On the other hand, however, the method would be very wasteful and costly where only a small number of persons has to be carried. No seats were provided on the platform, and beyond the fencing, the only objects rising above the platform levels were vertical wooden posts about 3 feet 6 inches high, terminating above in a wooden knob to aid persons in passing from one platform to another.

Mining and Metallurgical Section.

Stated Meeting held Wednesday, December 12, 1900.

TALLOW CAVE, NORTH DORSET, VT., AND MARBLE NATURAL BRIDGE, NORTH ADAMS, MASS.

By Edwin Swift Balch, Member of the Institute.

Tallow Cave is situated on Dorset Mountain, southwest from North Dorset, Vt. It is about fifty minutes' walk distant from the railroad station, up a rather steep and rough mountain road. I visited it with my brother and one of the natives of North Dorset, on September 25, 1900. There is a sort of ravine with a little bluff at the top; under this is the cave. The entrance is low and narrow, just large enough to pass through easily, and the wall of the cave goes down

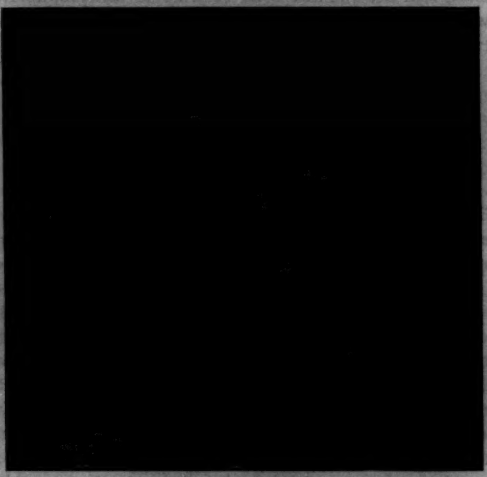
steeply for about 5 meters from the entrance. On this wall we found, fortunately, a rough ladder of two birch poles, with twelve rungs. At the bottom of the wall is a chamber some 4 meters wide and 6 or 7 meters long, which turns to the right and narrows towards the end. Here there is a pit some 4 meters deep, which forms a second and lower chamber, into which we could not descend, as there was no ladder; by throwing down some burning birchbark, however, we could see that it was small.

The noteworthy feature about Tallow Cave is the mineralogical formation from which it obtains its name. The rock is a coarse white marble, which, at the entrance, seems as hard as other marble. Inside, 4 or 5 meters from the entrance, the walls, the roof and the floor might almost be described as soft. They are formed of, or covered with, a sticky, compact, whitish substance, not unlike putty in its consistency, and which can be cut out in lumps with a penknife. It certainly resembles tallow, only it is more solid. There are neither stalactites nor stalagmites within the cave, and, judging from my one visit, the temperatures are normal and there is no very abnormal excess of moisture. Mr. Thomas H. Garrett, the analytical chemist, and Dr. William H. Wahl have kindly analyzed samples of the "tallow" for me, and they report that it is carbonate of lime. It is, in any case, a rare formation, for I have visited perhaps a hundred caves and never seen anything like it.

I find, however, in M. Martel's recent book, "La Spéléologie," that a similar or, perhaps, identical substance has been found in three caves in Europe, and that it is called *mondmilch* (moon-milk), a name given by the Swiss peasants near Mount Pilatus, where it was first discovered. These European caves, however, are of ordinary limestone, while Tallow Cave is of marble, so that the "tallow" there is at any rate unusual. The explanation given by M. Martel is that *mondmilch* is carbonate of lime so thoroughly saturated with water that it cannot harden into stalactite.

Not far from Tallow Cave a deep sink hole called Purgatory is reported. After a careful and fatiguing search

through the dense forest, I am sorry to say that we were unable to locate it, although our guide professed to know the mountain. It is described as a funnel-shaped pit, in whose base is a vertical hole of unknown depth; and when big stones are thrown in they can be heard falling for several seconds. It must be a regular *aven*, as these pits are called in the limestone regions of Southern France. I have no doubt of the existence of this Purgatory, for we discovered



Natural bridge of marble, North Adams, Mass.

on Dorset Mountain two small holes which went down vertically out of sight, and also a large pit, perhaps 6 meters in length by 4 in width and 5 in depth, whose sides are nearly sheer.

In the town limits of North Adams, Mass., is a remarkable natural bridge, which I visited last October. It is close by the Beaver quarry, whose marble is used in the manufacture of soda water. The bridge spans a little winding canyon, which has been cut out by water and

whose marble edges are rounded off, forming hollows and basins such as one sometimes sees in mountain streams. The bridge is of marble, and is about 4 meters long, 3 meters broad and some 3 meters thick. The canyon under it is 4 or 5 meters deep. Both in formation and appearance the bridge is entirely different from the one in the Shenandoah Valley or the little one on Cranberry Island, Me., the only others I have seen. Natural bridges at best are rare phenomena, and the one at North Adams is unique, as far as I know, in being formed of a true marble.

Stated Meeting, held Wednesday, December 12, 1900.

SUBTERRANEAN WATERS.

By Charles Morris.

The crust of the earth is only in a general sense a solid mass. In many localities it might be compared to a sponge, full of cavities and ramifying passages, and freely permeable to liquids. While in many places it is composed of dense rock or firm clay, through which water cannot make its way, in others it is rent and splintered, and large cavities here and there exist. Again, much of the material of the crust is porous, water passing somewhat freely through it, and in other localities water makes its way by a process of solution, dissolving and carrying off certain constituents of the rocks. As a result of this permeable condition much of the water which falls upon the earth's surface makes its way into the interior, penetrating the pores and cavities of the crust, which seems to be fully saturated with water.

What may be the actual quantity of water thus held in the earth's crust it is far beyond the present power of science to decide. It must be very great, since, in addition to the free liquid, water exists as a constituent of the hardest rocks. If restored to the surface it would doubtless be sufficient to raise considerably the ocean level, and perhaps to flood all the lower portions of the dry land. In that

remote period when the heated condition of the crust prevented the inflow of water, and the whole of earth's liquid element swelled the ocean, such a condition very probably existed. For ages, as the crust cooled, the waters made their way into the interior, until they reached a considerable depth, and the depression of the ocean level permitted a large section of the surface to emerge as dry land. One important result of this cooling of the surface and narrowing of the oceanic basins has been a decrease in evaporation and rainfall and a localization in the distribution of atmospheric waters, so that large regions of the surface have become deserts. This process of desiccation will doubtless continue in the future, but with great slowness, since the cooling of the earth's crust has become a very deliberate operation.

The quantity and distribution of the liquid contents of the crust are very imperfectly known. We can become aware of their distribution only by the upflow of water through springs and the piercing of the surface with wells. It is of interest to find that water exists at some level in almost every locality where such a well has been sunk, and that it is abundant at some of the greatest depths that have been reached, frequently under sufficient pressure to rise to the surface. There are, of course, vast reaches of strata destitute of water in a free state, but these dense strata have failed to check the downflow of the liquid element. Pierce them, and water is found below; pierce still lower strata, and water again outflows, often in large volume. Like the rocks themselves, the liquid contents of the crust seem to exist in successive strata, growing warmer as they lie at greater depths, and usually bearing mineral matter in solution, the product of the rocks through which they have made their way.

An interesting analogy may be shown to exist between the crust of the earth and the human body. The latter, solid exteriorly, is everywhere permeated with streams of flowing liquid, which pours forth wherever the surface is pierced. In the same manner, if we pierce the earth, its life blood gushes out, now flowing quietly, as from a vein, now spirt-

ing freely, as from an artery. Wherever we break through the skin of the great body of the earth the same results appear. In some of the most unpromising localities an abundance of subterranean water seems to exist. Even under the arid surface of the Sahara, the most extended of the earth's deserts, there appears to be an abundant supply of water at a moderate depth, which oozes forth freely at almost every point where an artesian well is sunk. The arid region of Southern California is partly irrigated from a similar subterranean stratum, and like conditions exist in other desert regions of the earth's surface, natural springs oozing up where artificial ones have not been made.

From this we may deduce that, so far as subterranean water is concerned, there is no marked difference between regions of abundant rainfall and those of great aridity. Dry as the soil may be in one locality, moist as it may be in another, the boring-rod of the well-driver reveals a strikingly homogeneous condition in the depths of the crust, and an oasis is formed in the desert wherever there is a passage upward for the underground waters.

There is nothing surprising in this. Such a distribution of the subterranean waters is what we might naturally expect to find. Once penetrate to the sub-surface and we reach a region in which the diverse influences of aridity and precipitation fail to assert themselves. Though the surface distribution of water may be localized, the movement beneath the surface is likely to be general, the water following every channel and making its way by multitudinous avenues to regions far removed from its place of origin. While the surface water may flow through river channels to desert regions, the underground distribution is likely to be more general, since, while the surface represents but a single stratum, there are many underground strata, each affording special opportunities for distribution. While the arid regions of the surface are those of small rainfall, those of the interior are due to impermeable rock strata, and the two conditions are not likely to coincide. It is quite conceivable, indeed, that there may be a far more abundant supply of water beneath a desert than beneath a well-watered

region, if the strata in the former case are more permeable than in the latter. The movements of subterranean waters have been going on for ages, and their existing distribution is dependent far more upon freedom of underground flow than upon variation in surface rainfall.

If, now, we come to consider the conditions under which the interior water exists, it is impossible to accept a widespread popular conclusion to the effect that flowing streams and rivers of water exist in the depths of the earth's crust. Streams of this character are found in great caverns, and this has doubtless led to the conception that the underground waters exist largely as rivulets or rivers, flowing through interior channels as the blood flows through our veins.

The fact is, however, that, apart from the streams found in the cavities in limestone strata, which must somewhere find a passage to the surface, such conditions do not and cannot exist. There are no such deep-lying streams, no great rivers flowing within the earth's crust; the subterranean waters being either at rest, or moving sluggishly as they are drawn off.

The interior of the crust was, in all probability, saturated with water in far remote times, and it is impossible for this water to move except to the extent that it finds a surface vent. It is probably contained almost wholly in porous rocks, and but to a small extent in channels and cavities. For the same reason the inflow is limited, being dependent upon the outflow. A saturated sponge can take in no more water, even if plunged into a full vessel. And there can be no movement of water into its interior, except to the extent that water escapes from its surface. In like manner, if the earth's crust be once saturated, all its pores and cavities filled, no more water can enter, and there can be no movement of the water within except to the extent that the contained liquid has an opportunity to escape.

The most evident channels of escape are those of springs, yielding cold, warm or hot water as they come from varied depths. These are rarely sufficient in number or volume to create any active interior movement, and most generally have to do with superficial strata. They are not confined

to the land surface, but frequently open under water, occasionally forming the sole supply of lakes. As one example of this may be instanced Lake Bombon, in the island of Luzon, which has no visible inflow, but has a considerable river for its outflow.

The well may be regarded as an artificial spring, which taps water strata of varied depths, occasionally, no doubt, reaching very ancient accumulations, which have lain undisturbed for ages. If irrigation wells increase very largely in number, as they seem likely to do in the future, they may give rise to a somewhat active movement of the interior waters. The artesian outflow is, of course, limited in quantity, since the sources from which it draws need to be renewed from the surface, and the seepage downward is a deliberate process and not calculated to yield a rapid new supply. The quantity of water to be obtained from the earth's crust is, therefore, far from inexhaustible, and represents a supply that has been gathering for ages. It may be said further that this water cannot reach the surface except through the influence of pressure, this being usually, perhaps solely, a hydrostatic pressure operating from some supply of water at a higher level, and indicating that the interior waters are to a large extent in continuous contact. It may be, indeed, that the pressure of natural gas has its share in the upflow of water, as it probably has in that of petroleum.

As regards the depth to which water can descend in the earth's crust, it is to a large extent an open question. Professor King, in his able study of this subject, considers that water may reach to a depth of more than 10,000 feet, —how much more he does not venture to suggest. If the crust were permeable to an indefinite distance downward, and water could descend unchecked, a vast volume would be necessary to produce saturation, but there can be no doubt that the rocks grow denser and less permeable as depth increases. The elevation of mountain ranges and the deposition of thick strata of new rock material have undoubtedly greatly compressed the underlying rocks, decreased their porosity, and forced out much of their more

ancient water contents, and it is possible that in this way a limiting layer may eventually be formed through which no water can penetrate. Yet at any time the rending action of earthquakes seems capable of opening vast rents in the deeper rock layers, producing cavities sufficient to contain large bodies of water, and to permit the descent of this liquid element to much greater depths.

There appears to be a limiting agent different from this, and one not subject to the action of chance or accident, or to the possible existence of porous rocks at a much lower level than has been estimated. This is a stratum of heat, not of dense rock, and one that seems likely to constitute an effectual limit to the descent of water, its action being to reverse the descending tendency of the liquid substance and convert it into an ascending tendency. In other words, the heat at a certain depth must be sufficient to convert the water into steam, which seeks to force itself upward with an energy greater than that with which the superincumbent water seeks to descend. The pressure of water at great depths, it is true, considerably raises the evaporating point, but there is a limit of temperature at which no amount of pressure can overcome the tendency to vaporize, and where this degree of heat is reached the possible descent of water comes to an end.

There are facts which seem to indicate that this limiting layer of temperature varies in depth to a large extent in different regions of the earth. In the Yellowstone Valley, for instance, the phenomena might be held to prove that the inflowing water is converted into steam at a very moderate depth. The multitude of hot springs, the leaping geysers, the whole phenomena of the valley, appear to indicate a high degree of heat at no great distance beneath the surface, a temperature sufficient to vaporize the descending water and hurl it up again in boiling fountains. And the same might be held to be the case in the various other geyser regions of the earth.

This is only one of the phenomena supposed to be due to the conflict between water and heat in the earth's crust. There is another and a far more important one, that of

volcanic eruptions, which are by many held to be results of the conditions here considered. In the geyser, the steam and water have open vents and are free to escape. In the volcano the vents are closed and the imprisoned giant of steam has to force its way to the surface. The boiling lava, which here replaces the hot water of the geysers, is saturated with the water to which its force of uplift is due, and this, as it reaches the surface, flashes again into steam and rends the lava into dust, or so-called ashes. The earthquake, which so often accompanies the eruption, is a result of the same cause, and testifies to the throes of the imprisoned giant in its mighty effort to break its bonds. The whole phenomenon is a striking example of the limitation of the descent of water through the influence of internal heat. This view, of course, is hypothetical, but as an instance in its favor I may refer to the remarkable eruption of Krakatoa in 1883. The suddenness and extreme violence of this eruption suggest the probability that some new opened crevice or cavity admitted the ocean waters in great volume to the heated strata of the mountain depths, and that these waters were converted explosively into steam, which expanded with a force sufficient to blow the mountain into fragments and hurl its debris miles into the air.

While it is possible that the existence of geysers and volcanoes indicates marked differences in the depth of the superheated rock layer, this is by no means necessarily the case. It may simply indicate that they occur in the localities in which the crust is specially permeable to water, and that such results are likely to occur wherever water is able to make its way downward to a sufficient depth. It may be suggested that unbroken strata of dense rock check the deep descent of water throughout the greater part of the earth's crust, and that it is able to reach the superheated strata only in the limited localities to which the phenomena in question are confined, and also that some of the effects named are likely to appear wherever and whenever the subterranean water does penetrate to this depth.

These considerations lead to the interesting conclusion that the most vigorous activities of the earth's crust—the

volcanic eruption, the earthquake and the geyser—may be largely or wholly due to the action of subterranean water. The same may be said of other activities of the crust. The slipping of strata, to which some earthquakes are credited, may be caused by the solvent action of water, and the lateral pressure to which mountain elevation is due is held to be a result of surface denudation and the heaping up of new strata beneath the ocean waters.

There is a second very important service rendered by water, that of the cooling of the earth's crust. In the primeval period the surface waters were constantly rising as vapor and conveying the superficial heat upwards, to be radiated from the atmosphere into space. In the succeeding period the subterranean water became engaged in similar service. Heated in the lower strata, it rose as the hot spring or the geyser, and in the form of explosive steam it hurled great masses of molten rock to the surface, there to yield its heat to the air. The volume of heat thus conveyed in a century to the surface is very considerable, and in former times was probably much more so. It may much exceed that which reaches the surface by the slow process of conduction.

Subterranean water would thus appear to have long been an agent of the utmost service to the earth, giving rise to the great activities of the crust and aiding essentially in cooling its interior. What will be the future record of this useful agent it is difficult to say. As the crust continues to cool, the waters may make their way to lower depths, unless checked by a general layer of impermeable rock. The cooling of the rocks will also tend to make them more capable of water absorption, and it has been suggested that the ocean waters may all eventually be swallowed up in this way, and the earth become a dry and dead planet like the moon.

This at least we can be sure of, that if such an event takes place it will be at some very remote period in the future. The seepage of water into the earth has long been decreasing with the decrease in the area of rainfall. If the oceans should grow narrower by the partial absorption of

their water, the rainless area will grow still more extensive and the area of seepage become more contracted. Civilization is adding to this effect by the removal of the forests. The water once held in their mold and gradually penetrating the surface now hastens downward to the streams and adds much less than formerly to the subterranean supply. As desiccation increases nature will continue what man has begun, the forest area narrowing and the waters rushing with less resistance to the sea. These influences must greatly check the possible future disappearance of the ocean waters within the crust, and whatever the final result may be, many millions of years must pass before the earth can become, from this cause, unfitted for the habitation of man.

DISCUSSION.

PROF. F. L. GARRISON suggested that some of the effects which Mr. Morris attributed to underground action might more probably be due to atmospheric conditions, such as aridity, etc.

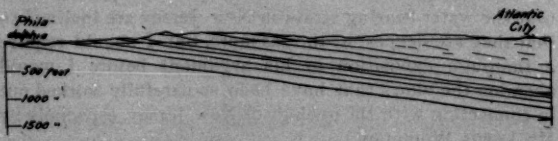
MR. J. C. TRAUTWINE, JR.:—In connection with the water supply of Philadelphia, suggestions have been received from time to time looking to the utilization of subterranean supplies by means of artesian wells.

From what I know of the geology of Philadelphia, and of the gneiss and mica schist upon which it appears to rest, I have always been skeptical as to the existence, under the city, of strata favorable to the formation of true artesian wells, which, I have supposed, could hardly be looked for below the relatively ancient rocks which immediately underlie the Philadelphia clays and gravels. I should be glad if any light could be thrown upon this branch of the subject.

DR. HENRY LEFFMANN:—Whatever may be the nature of the waters under the earth in this region, it is a matter of experience that deep wells generally yield a supply, but that the quality and quantity are often unsatisfactory. In many cases the water contains so large an amount of iron compounds as to be unsuitable for ordinary uses. Several wells in the business section of the city have been aban-

doned for this reason. Chlorides, principally, of course, sodium chloride, and calcium compounds, are also apt to be present in large amounts. A well of about 533 feet deep near the mouth of the Schuylkill River yields water containing considerable sodium chloride, but little of other substances, and this water has been used for some time both by human beings and farm animals for drinking without apparent injury. A well at Ninth and Mifflin and one near Hestonville also yield good waters. On the other hand, a well over 2,000 feet deep, near Broad and Green Streets, yields but little water, and, judging from my analysis, this is derived from the subsoil and not from a deep water-bearing stratum.

MR. JAMES CHRISTIE mentioned artesian wells in and near the northern portion of the city, especially in the neighborhood of Pencoyd, which yielded fairly, but the water of which was highly impregnated with magnesia, so much so that the employés of the Pencoyd Iron Works complained of intestinal troubles as a result of using it.



MR. TRAUTWINE sketched upon the blackboard a geological cross-section of Southern New Jersey between Philadelphia and Atlantic City, as given on a map prepared by the New Jersey State Geological Survey, showing alternating strata of sand and marl sloping gently from the Delaware River to the Atlantic Ocean, and underlaid, at least in the vicinity of Philadelphia, by the older rocks already mentioned. It will be seen that, according to this section, the deep artesian wells sunk near the seashore really tap the outflow from the vast natural sand filter bed formed by the sandy plains of Southern New Jersey, those nearest the coast intercepting the greatest number of these water-bearing strata, while near the Delaware River only the lower most of these strata are met with.

During recent years a company proposed to make a large excavation close by the Delaware River on the New Jersey side at Palmyra, opposite the Lardner's Point or Frankford Pumping Station of the Philadelphia Water Works. This excavation, it was argued, would be filled with pure water which could then be led in pipes laid under the river to the Lardner's Point Station, and thence pumped to reservoirs or into the distribution instead of using the unpurified Delaware River water as at present.

In correspondence had in connection with this scheme, the promoters expressed the view that the excavation would be filled by water drawn from the State of New Jersey in the near vicinity, but it has always seemed to me that if reliance can be placed upon the cross-section here shown, we should expect rather that the excavation would be filled by water filtering into it from the Delaware River through the intervening mass of sand and silt.

DR. LEFFMANN:—I do not know what data Mr. Trautwine's correspondent has that should lead him to reject the view that the water-bearing strata in New Jersey are inclined so that they are deepest at the seashore, but I should require a thorough exposition of his argument before I would abandon the views that have been so carefully worked out in connection with the geology of New Jersey, especially by Mr. Lewis Woolman.

I have found the water yielded by the new artesian wells at Camden analogous, in composition, with filtered Delaware River water. At Atlantic City, the artesian wells at Haddon Hall, and other wells of about 800 to 900 feet depth, gave a very satisfactory water, low in total solids, while both the deeper and the shallower wells gave much less satisfactory water, and wells sunk midway between Atlantic City and Philadelphia gave water heavily charged with iron. The water of the artesian well at Asbury Park is heavily charged with iron in solution, which, by the action of the air injected into it by the Pohlé air-lift pump, becomes further oxidized and reaches the surface carried in suspension, and is filtered out.

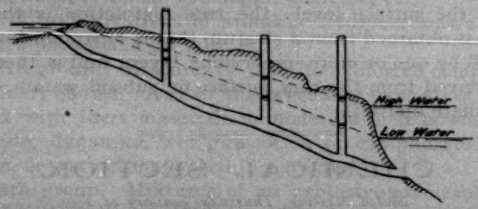
Geyser waters are very rich in silicic acid. In this

respect they differ from most deep waters, and it is probable that a powerful dissociation action takes place when very hot water under pressure comes in contact with the ordinary rock silicates.

Apropos to this, I may mention a laboratory experiment in which I was obliged to immerse a glass vessel for some time in hot water under high pressure. The glass in this case showed evidence of having been attacked and partially dissolved by the water.

MR. CHRISTIE mentioned a fresh-water well near the seashore, the level of which rose and fell with the tide.

MR. TRAUTWINE:—The rise and fall of the level of the water corresponding to the rise and fall of the level of the tide may readily be explained by the accompanying sketch illustrating the flow of water from a higher to a lower reser-



voir through a pipe provided with piezometers, or tubes indicating the pressure.

As the water flows from the higher reservoir, through the pipe, to the lower reservoir, the levels of the columns in the piezometers gradually become lower as we proceed from the upper to the lower reservoir; for, in each portion of the pipe, a part of the pressure existing at the upper end of such portion is expended in overcoming resistances in such portion.

If now, by any cause, as by the fall of the tide in the ocean, the level of the lower reservoir be lowered, that in the upper reservoir remaining constant, the hydraulic grade (or line joining the tops of the columns in the piezometers) will be correspondingly lowered.

The lowering of the level in the lower reservoir, of course,

increases the total head under which the water is flowing, and which is equal to the difference between the water levels in the two reservoirs. This increase in the total head causes an increase in velocity throughout the pipe, with a consequent diminution in the pressure at each point.

This seems to be in general analogous to the case of wells supplied from a higher district further inland, each well being in fact a piezometer standing upon the water-bearing stratum through which the flow is proceeding outward to the ocean, and it is therefore only reasonable to expect that the levels in these wells, especially those near the sea, would show a correspondence with the levels in the ocean.

Dr. Leffmann:—I think it would be a great mistake to limit the term artesian to wells that furnish water that rises above the surface level; the true distinction is that the water is obtained from a stratum that is separated from the subsoil by one or more impervious layers, and is, therefore, not derived from the rain, surface or subsoil waters of the immediate district.

CHEMICAL SECTION.

Stated Meeting, Thursday, January 24, 1901.

A BRIEF SKETCH OF THE ESSENTIAL REQUISITES OF "POWDER" AS DISTINGUISHED FROM "EXPLOSIVES."

By Dr. W. J. Williams.
(Being the Address of the Retiring President.)

In many minds, probably, the question arises, "What is the difference between a 'powder' and an 'explosive?' Are they not 'almost synonymous,' or at any rate are not all powders also 'explosives?'" In the ordinary acceptance of the terms the reply would be "yes," and yet in the military technical use of the words the difference is great.

"Powder" is a means of propulsion for projectiles. "Explosive" is a means for production of powerful shattering effects.

Explosives, in the broad use of the term, are classified by Berthelot in eight distinct groups, which may be summarized thus:

First group. Explosive gases.

Second group. Gaseous mixtures capable of detonation, formed by the combination of chlorine, oxygen or nitrogen oxides with hydrogen or hydrocarbon gases or vapors.

Third group. Explosive inorganic compounds that can be detonated by shock, friction or heat.

Fourth group. Explosive organic compounds, definite bodies, solid or liquid, that can be detonated by heat, friction or shock; for example:

(*a*) Nitric esters or nitric ethers, such as nitro-glycerine.

(*b*) Nitric derivatives of carbohydrates, viz., cotton, paper, wood, cellulose and sugar, dextrine, etc.

(*c*) Nitro derivatives of aromatic hydrocarbons, such as tri-nitro-phenol and its salts, etc.

Fifth group. Mixtures of definite explosive compounds with inert bodies. Any of the preceding explosives can be mixed with inert materials to moderate their powder; for example, dynamite, wet gun-cotton or camphorated gun-cotton, or gun cotton soaked in paraffine.

Sixth group. Mixtures of an explosive oxidizable compound with a non-explosive oxidizer, to complete the combustion.

Seventh group. (*a*) Mixtures with an explosive oxidizing base, a mixture of an explosive with an excess of oxygen (nitro-glycerine) with an oxidizable body, such as carbon-dynamite.

(*b*) Analogous mixtures in which the oxidizing and oxidizable substances are both explosives, such as blasting-gelatine, gum-dynamite.

Eighth group. Mixtures of oxidizable and oxidizing bodies neither of which is explosive separately, which include black powder, $KNO_3 + S + C$, and powders formed by mixing hydrocarbon compounds, charcoal, coal, wood, cellulose, starch, etc., or sulphur and metals with nitrates of potassium, sodium, barium, lead and many others.

The substances enumerated above are all "explosives,"

but very few, however, could be classed as "powders," and I will endeavor to show some of the essential requirements of a "powder" as distinguished from an "explosive."

Explosives may be subdivided into two classes, "explosive mixtures" and "explosive compounds." "Explosive mixtures" are intimate mechanical mixtures of components, but these components are not in chemical combination.

In "explosive compounds" the elements are chemically combined, producing an explosive wherein the combustible and the oxidizer are both contained in the same "molecule;" hence it is easy to understand that its action is infinitely more sudden and violent than that of the most intimate mechanical mixtures.

Explosive compounds may be divided into five classes, according to Major J. P. Cundill, R.A., and Lieutenant W. Walke's very convenient classification, which may be summarized as:

(1) Nitro substitution compounds.
(2) Nitric ethers or esters.
(3) Explosives of the Sprengel class.
(4) Fulminates, amides and similar compounds.
(5) Smokeless powders.

Many persons well acquainted with the chemistry of explosive compounds apparently fail to grasp the military technical difference between explosives and powders. The general idea seems to be, the more energy and power that can be condensed in a given weight, the better the explosive or powder. While the storage of great power is a most important element of the problem, yet there are others which require careful consideration in the production of a good service powder.

In general terms of differentiation one might define a "powder" as an explosive wherein the chemical changes are comparatively slow or progressive, or that the whole of the power is not released in the shortest possible period of time, but gradually, progressively, and if possible at a uniformly increasing rate. An "explosive," on the other hand, should develop its total energy in the shortest possible period of time; concentrated, as one might say, in one

powerful shock. Briefly, a powder *pushes*. An explosive *strikes* a sudden smashing, shattering blow. A powder *burns;* an explosive *detonates*. What then are the essential, and to some extent distinctive, requisites of a "powder?" These may be summarized as follows:

(1) The velocity developed.
(2) The pressure attained.
(3) Specific gravity and gravimetric density.
(4) Granulation.
(5) Temperature attained during combustion.
(6) Susceptibility to ignition.
(7) "Smoke" and ash.
(8) Friability.
(9) Sensitiveness to shock.
(10) Suitability for loading by machinery.
(11) Sensitiveness to environment, such as heat, moisture, etc.
(12) Stability.

Let us consider the first two conditions:

(1) The powder should develop a high velocity of projectile, and

(2) The pressure must be kept within prescribed limits, fixed by the strength and endurance of the gun.

To fulfil the first condition, the evolution of gas should be continuous and at an increasing rate to keep up a well-sustained pressure on the base of the projectile, because, as the projectile travels, the area of chamber (gas) space is constantly increasing; yet, to fulfil condition No. 2, the gas must not be developed too fast or the pressure on the barrel becomes too great. These two conditions alone present a very pretty problem, viz., to obtain highest possible velocity, *i. e.*, propulsive effect, and yet to keep the pressure within well-defined limits. The velocity of the ·30-inch caliber Krag-Jorgensen rifle bullet should be at least 1,960 feet per second (53 feet from muzzle of rifle), while the pressure should not exceed an average of 38,000 pounds per square inch, with a maximum of 45,000 pounds for any single round.

(3) Specific gravity and gravimetric density.

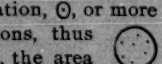
As we have already seen in the case of powder, a high velocity must be attained, yet with comparatively low pressure; and here comes in a third condition which, while not obligatory, is very desirable, viz., the power should be contained in a quantity of powder *limited by the content of the powder space in the cartridge case now in use*, to obviate the necessity of constructing arms of a new pattern to suit the new powder. While this space is not an absolutely fixed quantity, yet it is confined within very narrow limits. Obviously it cannot exceed the total cubical content of the case between the primer and the base of bullet; it may, however, be somewhat less, as this space need not necessarily be entirely filled. This question reduces itself then to a consideration of the specific gravity, the gravimetric density and the granulation of the powder. Specific gravity is so well known a term that there is no need to define it. In the case of a "powder" it is a secondary consideration, though of greater importance in an "explosive." On the other hand, gravimetric density becomes an important consideration. This is not easy to define; perhaps the best definition is that given by Lieut. Willoughby Walke, viz., "as the ratio which the weight of a given volume of the substance, including air and other interstitial spaces, bears to the weight of an equal volume of the standard (water) taken at 15·5° C. and 760 millimeters." As it is generally assumed that 1,000 ounces of water occupy a cubic foot, the gravimetric density is usually represented in terms of "ounces per cubic foot."

In the case of "powders", intended for the ·30-inch caliber rifle now in service, the gravimetric density is one of the points to be considered. It should be such that from 30 to 40 grains will, at least approximately, fill the powder space of the cartridge case. The gravimetric density is to some extent a question of "granulation" or of the form of grain in which the powder is manufactured, and to some extent a question of the ingredients of the powder.

It is obvious that gravimetric density is not dependent on specific gravity. A very dense powder may show a much lower "gravimetric density" than a powder of low specific gravity.

With explosives for shells, or bursting charges, the case is somewhat different. Here the object is to get as much potential energy as possible (not taking "sensitiveness" and other qualities into consideration) into a given space. In this case, then, a high gravimetric density is desirable. On comparing explosives about equal in gravimetric density, the one with the higher specific gravity is the better adapted (other qualities not now being considered) for such purposes, as it is obvious that the higher the specific gravity, the greater is the potential energy "maximum effort" developed by equal volumes of explosive. If possible, an explosive should be packed solid in a shell, avoiding air spaces and making its gravimetric density as nearly equal to its specific gravity as possible.

Briefly, and in general terms, for powders the gravimetric density must be such as to fulfil the conditions given above; for explosives, generally speaking, a high gravimetric density and specific gravity are desirable.

(4) As mentioned before, the "granulation" of a powder is an important factor in determining its gravimetric density. It is also of importance from another point of view, as the shape and size of the grains determine to a large extent the speed of combustion, and consequently the "velocity" imparted to the projectile and the "pressure" exerted on the gun, which is dependent on the evolution of gas at the proper rate as the projectile moves forward in the barrel. Opinions differ largely as to the best form of grain. It is generally conceded, however, that to meet the requirements of the case the ignition surface should be as nearly constant as possible. This is especially desirable in rifles of large caliber. Hence cannon powders are manufactured generally either in thin flat, or sometimes striated, strips, or as cylindrical rods or cords, solid or preferably perforated either with a single longitudinal perforation, ⊙, or more often with several longitudinal perforations, thus 
It is obvious that, as combustion proceeds, the area of exterior surface is constantly diminishing; but as the area of each of the perforations (or channels) is constantly increasing, this tends to keep up an approximately

constant evolution of gas. Moreover, as the rate of combustion increases with the pressure, this also tends to accelerate the evolution of gas as the charge is in process of combustion. The best or most effective form of grain for cannon is, as yet, an undecided question. Some experts favor one form, some another. The size of the grain varies with the caliber of the piece. Guns of 3·2 inches diameter take a grain about ½ inch long by ¼ inch diameter. Larger caliber guns have larger grains proportionately as the weight of charge increases. The larger the grain, the slower the rate of combustion, other things being equal.

For ·30-inch caliber rifles the granulation is, of course, much smaller. The grains are measured by sieving and should be of such a size as to pass through apertures 0·06 to 0·08 inch diameter and be held on a sieve with apertures 0·03 inch diameter.

Some rifle powders are made in the shape of thin flat discs, nearly square, measuring about ·075 inch by ·075 inch by ·01 inch thick; some cannon powders of the same shape, but of larger dimensions, about ·4 inch by ·4 inch by 0·025 inch.

For revolvers the grain is usually finer and smaller than rifle powder. It passes through 0·03-inch apertures and yet is a distinct grain and *not* fine dust.

(5) It is very desirable that the temperature attained during the combustion of the powder charge should be kept as low as possible, for the greater the heat developed, the greater the erosion or wear of the bore of the piece. This not only rapidly destroys the weapon and shortens its length of service, but also impairs its accuracy and reduces the velocity of the projectile in a comparatively short time on account of the escape of gas around the projectile while it is passing over the eroded portion of the bore. For this reason many consider nitro-glycerine a somewhat undesirable ingredient in smokeless powders, and its use is avoided, in a greater or less degree, especially when heavy charges are required. Others consider the advantages of nitro-glycerine more than balance its objectionable quality of producing very high temperatures and consequently con-

siderable erosion, and continue its use, seeking to modify its erosive action by admixture of hydrocarbons as coolers. The superior balistic qualities of nitro-glycerine powders are due to the heat produced by more perfect combustion, the nitro-glycerine furnishing the oxygen. This best preserves the tension of gases and sustains the pressure.

The powder used in the British service, cordite, contains as much as 57 per cent. nitro-glycerine, but it is said the guns rapidly deteriorate from erosion. The further discussion of this point is, however, outside the scope of this paper.

(6) A powder should be readily ignited by the service primer. It is, of course, essential that ignition should not fail (or cause "miss-fires") nor be delayed (producing "hang-fires"). Difficulty of ignition is therefore a serious defect in a powder, while at the same time too easy inflammability is equally undesirable, though this objection is seldom met with in smokeless powders which have been properly manufactured and granulated.

(7) In these days when the advantages of a practically "smokeless" powder are established beyond question, it is scarcely necessary to advert to the fact that mineral salts, leaving unconsumed residues, or "ash," on combustion, are inadmissible in any than very small proportions. So-called "smokeless" powders are not absolutely smokeless; they leave a thin, hazy vapor which is quickly disseminated. Small admixtures of mineral salts may be permitted in service powders. From a practical point of view the ingredients of a service powder should leave very little ash on combustion, and consequently very little smoke. So-called smokeless powders for *sporting* purposes often contain large proportions of mineral salts. The production of a little smoke is of no particular consequence under the conditions, and the admixture of mineral salts naturally enables the manufacturer to make a much cheaper article, yet one fully equal to all the requirements of the case. In explosives used in field and siege shells the production of smoke is advantageous in that it permits observation of point of burst and correction of aim and interferes with similar observation of his own practice by the enemy.

(8) Another point which is of high importance and yet is frequently entirely overlooked, is the friability of the powder or grain. A friable powder, the grains of which are easily broken, or one which easily rubs to dust from the attrition of one grain against another, during transportation or any other cause, is very undesirable. The presence of powder dust in a cartridge may be a source of great danger, as the dust ignites with great rapidity, causing undue pressures and strains on the weapon, and, indeed, occasionally causing (or at any rate presumably causing) such rapid combustion that it amounts to detonation.

The grain should, therefore, possess a considerable degree of toughness, or at least should not show brittleness.

In large grain cannon powders similar effects may be caused by the development of cracks in the grain, which means practically the multiplication of perforations, and, therefore, the increase of burning surface, resulting in great rapidity of combustion and possibly dangerous increase of pressure, which in extreme cases may also amount to detonation.

As smokeless powders are now "colloided," they are generally of a tough nature, very much like horn, yet occasionally they exhibit signs of friability in small grain powders, and of cracking in large grain powders, which is probably due to their having been dried too hurriedly, which causes too quick and uneven shrinkage, or these qualities may be due to the use of too large a proportion of solvent during the colloiding process. But no matter from what cause, friability and cracking are considered defects of the greatest importance.

(9) A powder should not be unduly sensitive to the shocks of ordinary transportation and handling. This is a defect scarcely ever met with under the present method of manufacture, where the more sensitive substances, such as nitro-glycerine, are so thoroughly incorporated with more insensitive substances, such as colloided gun-cotton, that there is no exudation of liquid nitro-glycerine. The present methods of colloiding have practically made exudation almost impossible. It is not often one meets with an unduly sensi-

tive powder—most of them withstand ordinary shocks very satisfactorily. An explosive intended as a bursting charge for armor-piercing shells should possess the power of sustaining extremely severe shock without explosion.

(10) A point frequently overlooked is the importance of having the powder in such a form as to be easily handled in the loading machines. Of course, if a powder is of good quality in other respects, save that it is not well adapted to the standard loading machines now in use, these machines can, as a general rule, be modified to meet the special requirements of such a powder; but the expense involved is great, and the said powder must show marked advantages over those now in use to warrant such a departure from existing conditions.

(11) A good powder should be able to withstand variable atmospheric and other conditions to which it is liable to be exposed during service or transportation, or similar conditions.

(*a*) *Heat.*—A powder may be required for use in every variation of climate from tropical to arctic conditions. The general effect of heat is to accelerate combustion and consequently increase the pressure in the weapon and the velocity of the projectile. A powder, then, to meet the service requirements in small arm rifles, must be such that exposure to a moderate heat—about 130° F.—must not increase the velocity above 100 f. s. from the standard nor the pressure above 45,000 pounds per square inch, either when the powder itself has been so exposed and is loaded into cartridges immediately, or when cartridges already loaded are so exposed and fired warm. It will be readily understood that exposure to a tropical temperature must not cause any chemical or other change. For instance, high temperature must not cause exudation of nitro-glycerine nor liquefaction of that or any other ingredient, nor loss of any ingredient by evaporation, nor decomposition of any kind.

(*b*) *Moisture.*—Exposure to an atmosphere saturated with aqueous vapor should not exert any marked deleterious influence on a powder. The general effect of such exposure is to reduce the rapidity of combustion and so diminish the

pressure in the arm and consequently the velocity of the projectile. If the small arm velocity is reduced 100 f. s. below standard, such a powder is not suited to service conditions. Of course, too, moisture has the effect of increasing the difficulty of ignition, and therefore causing "miss-" and "hang-fires." These remarks refer, of course, to powders which contain no especially hygroscopic ingredient (*e. g.*, sodium or ammonium nitrate), but yet can absorb a small percentage of moisture when exposed to a damp atmosphere. A good powder, then, should be able to resist moisture, and even if accidentally it becomes exposed to moisture it should be so constituted that when dried, either by exposure to ordinarily dry air or by artificial heat, it recovers its original condition and properties.

For "explosives" in the sense of "bursting charges" for shells, or for blasting purposes, this power of resisting moisture, or absence of hygroscopic properties, is not so essential, for when enclosed in the shell, or properly prepared more or less water-resisting case, the explosive is protected from these influences, and under ordinary conditions of storage retains its serviceable conditions. It is obvious, however, that service powders, whether for military or naval use, should be so constituted as to be practically non-absorbent, and for explosives this quality is very desirable.

(*c*) *Cold.*—A good powder should not be affected by cold, and should stand exposure to at least *minus* 40° C. for at least six hours without serious variation of its qualities. The effect of cold on the nitro-glycerine in dynamites is too well known to be dwelt on in this paper, and alternate heat and cold is apt to cause exudation or separation of the nitro-glycerine from its absorbent. It may be mentioned, however, that exposure to *minus* 40° C. does not have any material influence on well-made powders consisting of nitro-glycerine with gun-cotton; and certain other substances appear to be but little affected.

(12) All powders and explosives should be "stable," *i. e.*, there should be no decomposition by the reaction of one ingredient on another or by the influence of heat, light,

moisture, change of climate, etc. For instance, a rifle or revolver powder finely subdivided must withstand a temperature of 65½° C. for at least twenty minutes without emitting acid vapors as indicated by the discoloration of potassium iodide and starch paper partially moistened with dilute glycerine.

A cannon powder cut into thin slices about 0·020 inch thick should not cause discoloration under ten minutes at a temperature of 100° C.

Gun-cotton dried at about 46°–47° C. to constant weight and then exposed to the air of a room to absorb its normal proportion of moisture, viz., 1·5 to 2·0 per cent., should withstand a temperature of 65½°C. for at least thirty minutes without discoloring the potassium iodide and starch paper.

From these considerations it is obvious that there must be no free acid in a powder or explosive where "stability" in this sense is required. Each ingredient must be carefully purified and all free acid removed or neutralized. Certain acids such as picric acid and other nitro-substitution compounds do not seem to affect the KI and starch paper, unless exposed for a longer time than one (1) hour or thereabouts, but as a general rule free acid or nitrogen oxides will discolor the paper very quickly.

Traces of ether act quickly, probably from the production of aldehyde. Alcohol which has slowly oxidized to aldehyde, or perhaps has undergone acetous fermentation, will discolor the paper rapidly; in general, any oxidizer will act thus, so the ingredients of a powder should not only be free from acid, but also from any substance which liberates oxygen at the temperature specified. Acetic acid rapidly discolors the paper; oxalic acid (like picric) does not seem to affect it, at any rate in less than one (1) hour.

It is well known that nitro-glycerine if not carefully washed and neutralized from all acid will slowly decompose spontaneously. Such explosives should be treated with alkaline carbonates, or carbonates of the alkaline earths, to prevent this tendency to acidification on long storage or under the influence of heat and moisture.

Even perfectly neutral nitro-glycerine will slowly de-

compose under the influence of moderate heat. If the temperature does not exceed 45° C. there is no decomposition and the nitro-glycerine remains "stable" to the KI paper. A few weeks' exposure to a temperature between 45° and 50° C. will, however, much impair the "heat test," while it is rare to find a sample of nitro-glycerine that will stand 65° C. for more than thirty (30) minutes. If, however, it stands over ten (10) minutes, it is considered stable. From 45° to 50° C. may be considered the critical temperature of nitro-glycerine.

A temperature of 180° C. explodes nitro-glycerine, though very small quantities can, with care, be raised to 200° or 210° C. without explosion.

Gun-cotton, too, will slowly decompose if the acid is not carefully washed out and neutralized. If traces of acid are present, gun-cotton will begin to decompose by mere exposure to light. Very carefully prepared gun-cotton can, as Dr. Abel has shown, be kept at a temperature of about 50° C. for several months without decomposition, and even strong sunlight does not cause its decomposition. The critical temperature of gun-cotton appears to be about 45° C., as a higher temperature is apt to decompose any but exceptionally carefully prepared samples. When gun-cotton is stored in large quantities it is customary to wet it, and dry out the moisture as required. Wet gun-cotton seems perfectly safe. Good gun-cotton ignites at about 180° C., though there is a slight variation in temperature according as to whether the heat is raised gradually or quickly.

All nitro-compounds, unless most carefully prepared and purified, are easily decomposed by comparatively low temperatures and even by exposure to light. It is, therefore, essential, even when dealing with them on the manufacturing scale, to obtain absolutely neutral products. Even traces of acidity are not only detrimental, but tend to become highly dangerous, after the lapse of a short time.

What has been said of nitro-glycerine and gun-cotton applies equally to the nitro-substitution compounds of the aromatic hydrocarbons. Unless prepared with the utmost care, they are liable to spontaneous decomposition which will probably lead to disastrous results.

The general idea, then, is that a "powder" must burn comparatively slowly, evolving gas at a gradually increasing rate, while an "explosive" should develop all its energy in the shortest possible space of time. Hence, for powders, the colloid condition in which the gun-cotton or mixtures of gun-cotton with nitro-glycerine and other explosives is prepared seems eminently well suited.

The granulation should be suited to the caliber of arm, so as to regulate to some degree at least the speed of evolution of gas and consequent pressure exerted.

"Powder" should be smokeless, while the production of smoke may be highly desirable in an "explosive."

An explosive should be highly insensitive to shock to a much greater degree than is necessary in a powder.

Perhaps this brief sketch of the requirements of a powder may be of value as roughly indicating some of the more important conditions that should be fulfilled in the production of a powder suited to the present service conditions.

ROTARY TRANSFORMERS:

THEIR HISTORY, THEORY AND CHARACTERISTICS.*

By George W. Colles, A.B., M.E.

[*Prefatory Note.*—It is not pretended that this essay is entirely new; but neither is it a mere compilation or patchwork of others. It professes to take a broad, comprehensive review of such transforming devices as are included in its scope, or nearly allied thereto, tracing their evolution from crude beginnings to the refinements of to-day, and indicating the peculiarities of each by itself, as may seem of interest or importance, and its comparative merits or demerits in relation to others. So far as the author knows, no such treatment has hitherto been given to the subject. Although a great deal has been written in recent years, all that has as yet been written, so far as he has been able to find, is of fragmentary character, treating isolated phases or problems, and not even the single-coil rotary transformer has been accorded anything like a complete treatment. Perhaps the nearest approach to the latter is the paper of Prof. S. P. Thompson, delivered before the Institution of Electrical Engineers, in November, 1898; but this again, though furnish-

*A thesis presented in candidature for the degree of Master of Science, in the Columbian University, May, 1900.

ing a large number of interesting facts, is fragmentary and without apparent system.

Of the present essay, the historical matter is believed to be entirely new; and so, too, the classification and comparison of the different machines. The theory of the single-coil transformer, in which centers the greatest share of interest, is mostly digested and arranged from other sources; but here, too, will be found a number of facts or distinctions which it is believed have not yet been pointed out, or given the importance due them. The mathematics of the subject has been limited to such brief and general treatment as merely to indicate the mode of procedure, while the reader has been referred to the most important papers dealing with the subject, for such further information as he might desire; and the *results* hitherto arrived at have been given. But here also the mode of treatment has been in part original, in particular the equation for the heating of individual armature coils (under "Current Relations," *supra* Note 63), and the curves of Plate XX. The author would also call attention to the attempt at an analysis of the very peculiar case cited under "Pressure Relations" (at the end), which he thinks will prove interesting, although perhaps bold, no such attempt having been made by his authority, Professor Thompson. As to practical data, but very few could be given, as unfortunately very few are as yet at hand.

All the sources of information at the author's command have been drawn upon wherever they could offer assistance in the elucidation of the subject; and references have been given to original sources, wherever possible.]

The author was tempted to add to the above the alternative title "or continuous current transformers;" but in view of the restriction of that term, as generally understood, to the meaning of "dynamotors" or motor-generators employed only in connection with continuous currents, it has been omitted. The discussion of the following pages is not, however, limited to the rotary transformer in its narrow sense, to wit, that of a species of dynamo-electric machine having an ordinary one-coil armature and provided with both commutator and slip-rings, although this, as its most important form, will receive the greater share of attention; but it is intended to be a general review of all forms of apparatus which have been devised for the purpose of transforming one form of electrical current into another, and which have rotating parts (which, as will be seen, appear to be a necessity wherever continuous currents are concerned); and, incidentally, other forms will be touched upon so far as is necessary or desirable to the illustration of the subject thus defined. In this way we shall obtain a juster view of the state and possibilities of the art than we could obtain

by considering merely the virtues and defects of the species in general use for this purpose.

The term "alternating current" (denoted by *A C*) will here be used in the sense of monophase alternating current; "direct current" (*D C*) as the synonym of continuous current; polyphase (*P P C*), 2-phase (*2 P C*), 3-phase (*3 P C*), etc., in their usual significations. As has been shown by Steinmetz[1] and others, there is a radical distinction between the simple alternating and the polyphase form of current, due to the fact that in the former the energy transmitted fluctuates from zero to a maximum, along with the current; whereas in the latter the flow of energy is constant. This fact serves to differentiate the polyphase as completely from the alternating as from the continuous current, and to place it midway between them, resembling the former in its current wave and inductive or magnetic characteristics, the latter in its energy-flow and mechanical action upon dynamo-electric machinery.

In treating of current transformation we have therefore to consider these three kinds or species of current, and we may wish to transform our electrical energy—

I. In respect of pressure (pressure transformation):
   (1) Alternating,
   (2) Polyphase,
   (3) Continuous;
II. In respect of kind (species transformation):
   (4) Alternating and polyphase,
   (5) Polyphase and continuous,
   (6) Continuous and alternating;
III. In respect of frequency (frequency transformation):
   (7) Alternating,
   (8) Polyphase;
IV. In respect of phase-relations (phase transformation):
   (9) Polyphase.

These are the nine possible simple transformations. We may, perhaps, range them more conveniently with respect

[1] *Trans. A. I. E. E.*, V. 9, p. 93, Feb., 1892; and V. 12, p. 330, June, 1895.

to the different sorts of machinery adapted to accomplish them, as follows:

(1), (2) and (9) may in all cases best be accomplished by stationary transformers; though for (9), rotary apparatus is occasionally used.

(4) is perhaps most often accomplished by stationary apparatus, although rotary is preferable in many cases.

For (3), (5) and (6), involving continuous currents, and for (7) and (8), involving frequency-changing, apparatus with moving parts, so far as we can see, must be used. We cannot say positively but that some practical stationary mode of frequency-changing may be devised; but, on fundamental principles, it appears certain, as will be hereafter more fully shown, that wherever continuous currents are concerned, no transformation, in the proper sense of the word, can be accomplished without moving parts.

The following pages will be confined principally to transformations (3), (5) and (6), which are the kinds oftenest occurring in practice where rotary transformers are desired; touching lightly upon (7) and (8), and upon the others only as may be necessary in the elucidation of our main thesis.

These simple transformations are, however, rarely found alone, but usually associated with one or more others; thus, a species transformation is usually associated with a pressure transformation, and sometimes with a frequency transformation, or both; a phase transformation may be superadded, or, as in some recent inventions, may form an intermediate step to the species transformation. The question whether all these transformations shall be made at once and in one machine, or severally and in separate machines, is one of expediency rather than possibility; for while it is, theoretically at least, always possible to construct a machine to accomplish them all, it has been often, and indeed usually, found advisable not to do so, on account of practical difficulties or defects in the apparatus so constructed. Now, the imperfection and drawbacks of such a method, to wit, the use of two or more distinct machines through each of which all our energy must pass before we get it in the desired form, both as respects high plant-cost and

low efficiency, are obvious; and it is therefore to overcoming this necessity, by the perfection of the single machine, that the future progress of the art must be principally directed—not solely to the perfection of the common one-coil rotary transformer as it exists; which, providing as it does for only one simple transformation, must always be an imperfect means of reaching the desired end.

We may, therefore, appropriately proceed by a review of existing apparatus of all kinds, considering as we go the peculiar properties of the most important types. It will be most useful to proceed by the inductive method, or in the historical order in which the improvements arose; but first marking out the several distinct types or lines of development which distinguish existing forms, and which may be summed up as follows:

I. *The Rectifier Type.*—This type is far the most ancient, dating back, according to Thompson,[1] as far as 1838, and being in common use in 1869, when they were used for the field magnets of self-exciting alternators. This apparatus can hardly be called a transformer in the proper sense, as it contains no inductive or other coils, being nothing more than a rotating commutator, whereby the pulsations of the alternating or polyphase current are commuted and rendered unidirectional, or, on the other hand, the direction of a continuous current is periodically reversed. In the former case the rectifier must be rotated synchronously by a donkey motor. A commutator of this sort is easily devised, and a number have been put on the market; but the device is crude and at best a makeshift, as no truly constant current can be produced, especially from a simple alternating current; on the other hand, a true alternating current is not produced by reversing the poles of a continuous current circuit. The main defect of this class of devices is, however, the common one of excessive sparking, owing to the fact that the circuit must be periodically broken at each reversal to avoid the alternative of short-circuiting the primary mains. The best known of these devices is perhaps the Pol-

[1] "Dynamo Electric Machinery," Fourth Edition, p. 652.

lak rectifier,[3] which takes the current only from the tops of the waves of electromotive force, and so insures greater uniformity, though at the expense of continuity. This machine has been used in the Ferranti station at London to charge a battery circuit. We may, however, dismiss this class of machine with this brief notice as somewhat apart from our subject, as well as unimportant.

II. *The Inductorium Type.*—Characterized by a series of induction coils, which may or may not be stationary, arranged in a circle and having their primary and secondary coils, one or both, connected to the respective segments of a commutator; the apparatus is not, in general, self-rotative or self-regulating, as in our common motor-transformer, but must be rotated by a donkey-motor or other external source of power. One or two commutators are used, according as a direct and alternating or two direct currents are wanted. In this class there are three well-marked subclasses:

(1) The stationary independent coil type, in which each induction coil is wound upon a separate core, and separately connected to the commutator or commutators through slip-rings. This, the oldest of transforming devices for direct currents (if we except the rectifier), has proved, in the hands of two ingenious French inventors, one of the best, if the fatal defect of sparking can be overcome.

(2) The stationary ring type, in which the separate induction coils are now wound together all upon one ring, which has two independent sets of coils wound thereon Gramme fashion, and connected to the commutator or commutators through slip-rings.

(3) The rotating ring type, identical with the former, except that to avoid the slip-ring connection and possibly to give stability to the rotation, the induction ring is mounted on the commutator-shaft. The "dynamotor" has not been reached, as no external fields are provided.

III. *The Motor-Generator Type.*—In this is included the very simple device of an independent generator coupled to a motor on the same shaft, or otherwise mechanically connected to it. Starting thus from an entirely different basis

[3] *Electrical Engineer* (N. Y.), V. 16, p. 238.

from either of the preceding, the two following types have been successively evolved.

IV. *The Dynamotor*[4] *Type.*—Here the two independent machines of the preceding type are merged into one—usually a single armature, sometimes two armatures, but always in one field, and always with independent primary and secondary coils; its use being practically confined to continuous currents only, with a commutator for each coil.

V. *The Rotary Transformer Type.*—Proceeding still one step further in the same lines, we reach the true rotary transformer; in which we have one machine, one armature and one coil only in that armature—in short, a dynamo of the ordinary drum or ring-wound type, but provided with two sets of connections to its armature coil, one of which *must* be a set of slip-rings for an alternating or polyphase current.

It should here be noted, that we have not taken the steps leading from the motor-generator to the rotary transformer type without serious sacrifices; for the first was at the expense of regulation, the second at the expense of a pressure transformation. So doubtful is the balance of advantage in favor of the rotary transformer, in fact, that even to-day the motor-generator is preferred in many cases, and it has not infrequently happened that, proving unsatisfactory, transformers have been taken out and replaced by the old motor-generator type.[5]

As will be seen, there are connecting links or transition forms between all these five types, and shading from one into the other.

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[4] The exceptions taken to this word by Professor Thompson and others, as both philologically bad and a misdescription, are entirely just. The lack of any other to fill its place, however, compels us to press it into use. The term "dynamotor" has come to have a more limited significance than the term "motor-generator" or "motor-dynamo," as is above sufficiently distinguished. Nor is it infrequent for a word of antecedents thus confessedly bad to be forced upon us against our will, and to obtain a place in the King's English in spite of us, as for instance, *sociology*, *ferromagnetic*, *bicycle*, *automobile*.

[5] See the discussion on "Rotatory Converters" in *Journal I. E. E.*, Vol. 27, pp. 705-717, *passim* (November, 1898).

MACHINES FOR CONTINUOUS CURRENTS ONLY.

THE INDUCTORIUM.

The earliest recorded device which can be called a transformer for continuous currents is probably that shown in Plate I, which is from the specification of a patent granted to R. K. Boyle[4] in 1875. It shows a

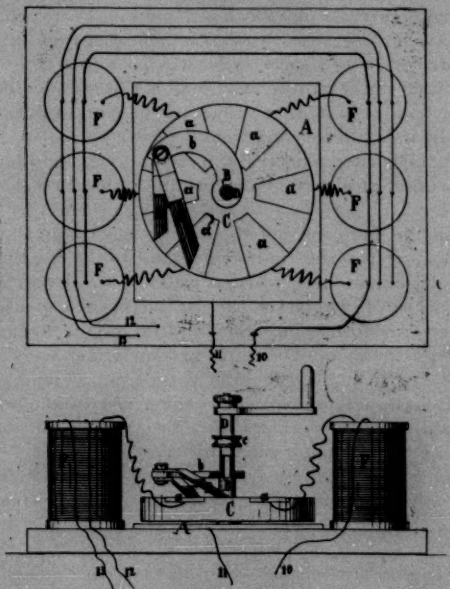


PLATE I.—Boylè's inductorium. 1875.

series of stationary induction coils *FF* whose primary leads are connected to the poles (10, 11) of a primary battery or other source of constant electromotive force, one directly, the other through a commutator *C* of the ordinary

[4] Patent No. 169,514, November 2, 1875. United States patents are meant unless otherwise indicated.

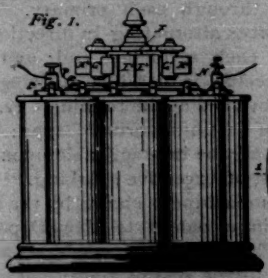
type, to each bar of which is connected the primary of one coil. The single brush (shown with two branches, *E E*) is connected to the free pole of a battery, so that, as the brush is rotated (by hand), a series of unidirectional current impulses is successively sent through each primary. This will cause electromotive forces alternating in direction to be induced successively in each secondary coil; and the secondaries being all connected in parallel, an irregular alternating E.M.F. will be obtained at the terminals 12, 13.[7] This apparatus is of the first or "inductorium" type; it is non-reversible, and would clearly be impracticable upon any considerable scale on account of excessive sparking.

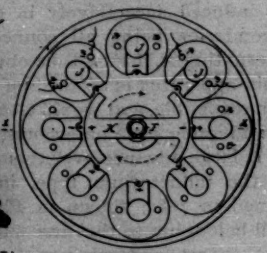
A large advance over this machine is shown by the next of the inductorium type, in a patent to Van Depoele[8] issued in 1882, shown in Plate II. This machine, while still belonging to the first subtype of the above classification, shows approaches to the more modern types in several directions. *J J* are the cores of the induction coils, whose primaries are connected in regular Gramme fashion around the bars of a stationary commutator, as shown in *Fig. 4*. Direct current enters at the brushes H^1 H^2, *Fig. 5*, which are rotated automatically by the permanent magnet *K*, *Fig. 3*, which is mounted on the same shaft and immediately opposite the upper row of poles of the cores *J*. A torque is set up in this magnet by giving it a certain lead over the brushes. As the latter rotate, a current is sent through the coils, thus divided into two halves by the brushes exactly as in a Gramme ring, the current in each coil being abruptly reversed in direction as its corresponding commutator seg-

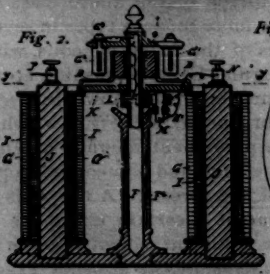
[7] This is not the mode of operation stated by the patentee, who appears to have supposed that the unidirectional primary impulses would produce unidirectional secondary currents, the pressure being raised as desired by properly proportioning the windings. It is clear, however, that this is not the case; for, the total quantity of electricity transferred in the secondary circuit in any direction being proportional to the energy of magnetization stored up in the cores of the coils *F*, and thus being zero at the close of operations, it follows that the current integral in the secondary coils must be equally positive and negative. We cannot, unfortunately, transform continuous current from one pressure to another by any such simple and convenient method.

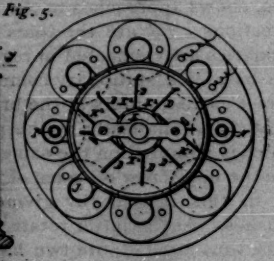
[8] No. 266,735, October 31, 1882.

ment is passed. A ragged alternating current is thus set up in each of the secondaries, which may be used separately or connected in series, as desired. As each coil is practically independent, there can be nothing like evenness or









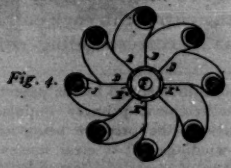


PLATE II.—Van Depoele's inductorium. 1882.

regularity in the secondary wave of electromotive force, and sparking at the brushes would here also seem to be a serious defect. This machine might be reversed, in which case it would run synchronously.

The next machine of the inductorium type to show itself belongs to the second subtype, where the additional advance is made of replacing the independent induction coils by a Gramme ring wound with the primary and secondary coils

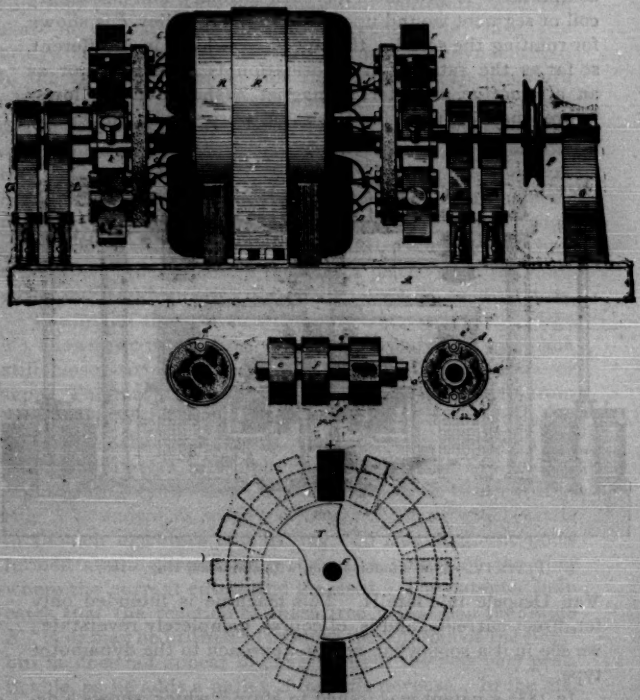


PLATE III.—Waterhouse's inductorium, with stationary ring. 1883.

placed in juxta- or superposition, and each connected to a separate commutator as in the dynamotor type. This is first shown in a patent to Waterhouse,[9] of 1883 (Plate III).

[9] No. 271,169, January 23, 1883.

The only rotating part in this machine is a spindle bearing a two-part commutator (*a*, *k*) and a pair of slip-rings (*e*, *f*; *l*, *m*) forming respectively the primary and secondary terminals, at each end; a separate brush bearing on the corresponding commutator is provided for each primary and secondary coil or segment wound upon the ring. A pulley *P* is shown for rotating the spindle, the speed of which is indifferent, so far as the ratio of transformation is concerned; or as an alternative, an internal magnet *T* (shown in the lower figure) may be used for the same purpose, as shown by

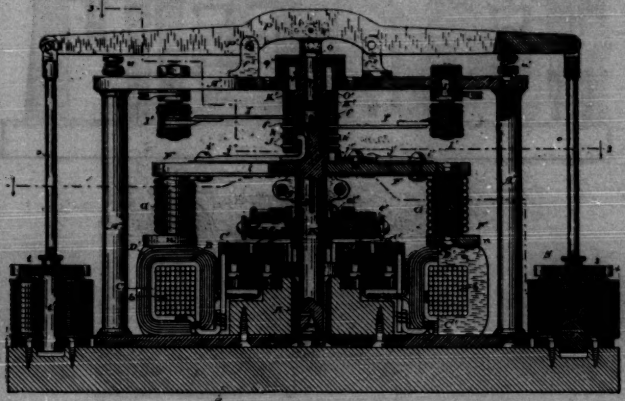


PLATE IV.—Main's inductorium, with stationary ring. 1887.

Van Depoele in Plate II. This machine is intended only for direct currents, and is, of course, completely reversible; we see in it a somewhat nearer approach to the dynamotor type.

In 1887 a patent was issued to Main,[10] which shows a device substantially identical with the foregoing in principle, though somewhat different in arrangement (Plate IV). The main difference lies in the essential part which is played by the magnetized bar—here called a "magnetic bridge"—

[10] No. 361,770, April 26, 1887.

which is employed to rotate the commutator brushes. This bar, *F*, is wound with coils, *G*, in the primary circuit and is made somewhat larger and placed at one side of the induction ring *C'*, which, with the commutators (*C*, *D*) and slip-rings (*f f*, *k k'*), are here shown in horizontal, and the shaft in vertical position. Now suppose this "magnetic bridge" made larger, so as to answer to a true dynamo-field to the ring *C'*, and make this ring rotate as an armature while the field thus formed remains fixed, and we have a true dynamotor. But the present machine, nevertheless, cannot be said to operate on the principle of a dynamotor; the "magnetic bridge" *F* is too insignificant to perform the regulating and magnetizing function of fields, or even to close the magnetic circuit induced in the stationary ring.

We now pass to the third subclass of the inductorium type of machines, wherein the ring is placed upon the shaft with and rotates with the commutator or commutators.

The first of these, from a patent to Gravier,[11] of 1883 (Plate V), shows two interesting transition forms which approach still closer to, without actually being of, the dynamotor type. The machine shown in the upper figures differs from that of the Waterhouse patent above described principally in the fact that the ring is made to rotate along with the two commutators to which it is attached, thus avoiding the slip-ring connection; and in addition, an external iron ring *K* is shown *to complete the magnetic circuit* which exists in all such machines and having two free magnetic poles formed at the diametrically opposite points of the ring where the current enters and leaves it. The patentee indicates that the reaction of these free poles upon the frame *K* "is or may be utilized to produce the rotation of the ring," but he does not appear to have thought the idea very practicable, as he adds a pulley *Z* for this purpose. In the machine shown in the lower figures the frame *K* is in the form of a ring surrounding the armature, which is stationary, and the machine otherwise substantially identical with the Waterhouse device.

[11] No. 276,390, April 24, 1883.

A similar device was patented to Edison[13] in the same year. The principle of closing the magnetic circuit is a substantial improvement in this class of device, just as it was

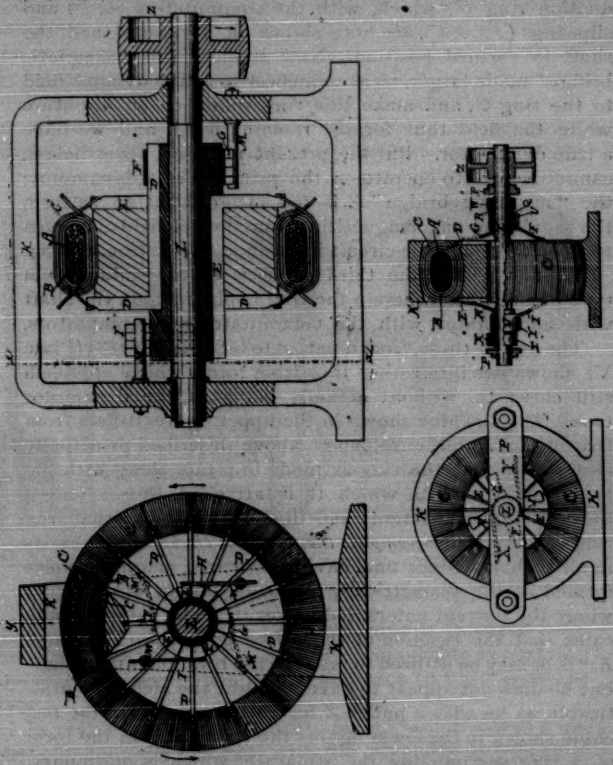


PLATE V.—Gravier's inductorium, with rotating ring. 1883.

in stationary transformers over the old Ruhmkorff coil. A still better way of accomplishing this is shown by Jehl,[13] in

[13] No. 278,418, May 29, 1883.
[13] No. 379,073, March 6, 1888.

a patent issued in 1888 (Plate VI). Here we have two Gramme rings in juxtaposition (*Fig. 2*); or one within the other (*Fig. 3*); or a ring surrounding a drum-wound core, as in *Fig. 5*. The primary is wound on one, the secondary on the other core, and the magnetic circuit is at all times completed by arranging the free poles of the two cores opposite each other, as indicated in the several figures. In *Figs. 2*

Fig. 1.

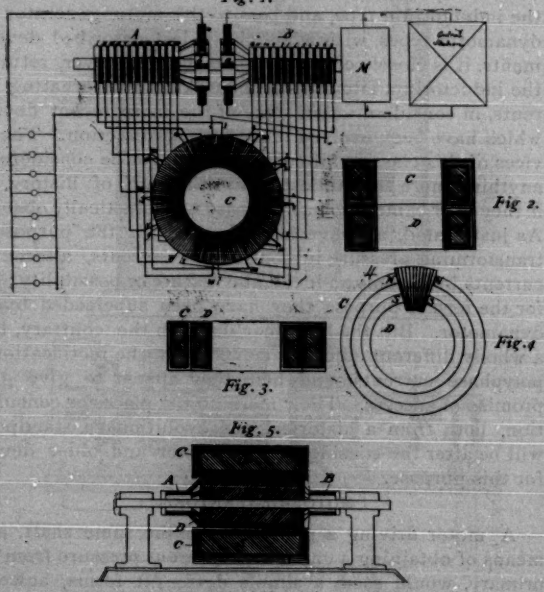


PLATE VI.—Jehl's inductorium. 1888.

and *3* the rings are stationary, and the individual coils are connected through slip-rings *A B*, to appropriate commutators *a b*, which are rotated by an independent source of power, as shown in *Fig. 1*; whereas in *Fig. 5* the induction rings are mounted on the shaft and rotated with their commutators. In neither case is there a suggestion of an ex-

ternal stationary field, nor would this here be a desirable addition. A slightly different form of this device is shown in a patent issued to Edison [14] as late as 1895; and it is claimed by the patentee that sparking is substantially suppressed by this arrangement, although the fact would seem somewhat doubtful. All of these machines are intended for use with continuous currents only.

We may here leave for the present the consideration of the inductorium type, and pass to the motor-generator and dynamotor types, with which, in its last described developments, it is closely connected; we shall, however, return to the inductorium later on when speaking of alternating currents, in consideration of some of the more recent devices, which have been evolved in a distinct direction. The devices of this class so far considered cannot be considered as anything more than milestones in the path of history, for, if they ever came into use, they are now practically obsolete. As just stated, all have been devised for the purpose of transforming pressure in continuous currents, alternating currents being only an incidental feature or possibility; and for the former purpose they have been superseded by the dynamotor. But the later machines, on the contrary, have a wholly different object in view, to wit, the rectification of polyphase currents, and here they appear to give great promise of success. Their more proper place for consideration, both from a historical and evolutionary standpoint, will be after the consideration of other and older devices for this purpose.

MOTOR-GENERATORS.

A motor driving a generator on the same shaft, as a means of obtaining a current of different pressure from the primary, would seem a simple device; it forms, however, the subject of a patent to Edison,[15] issued in 1881. In the patent the derived circuit serves to excite the field of the main generators, an arrangement now frequent in the case of alternating and polyphase generators.

This type of machine shades by various transition

[14] No. 534,208, February 12, 1895.
[15] No. 251,550, of Dec. 27, 1881.

shapes into the dynamotor proper, as exemplified in Plates VII and VIII.

The lower figure of Plate VII is from a patent to Thomson,[16] issued in 1887. Here an open coil constant current armature *V* is shown driving one of the same type, *W*, which yields alternating currents at the slip-rings *r*.

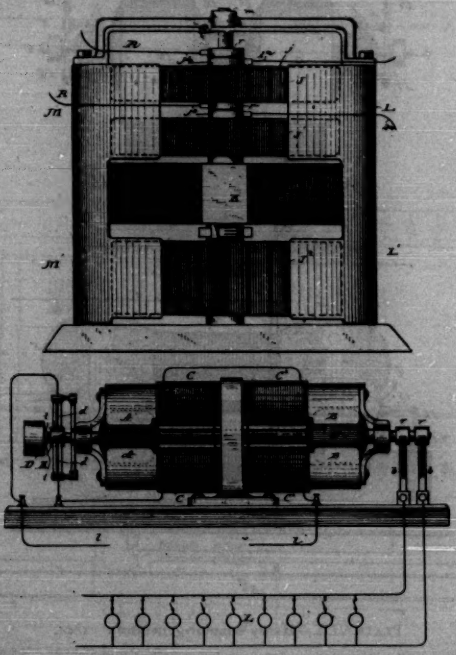


PLATE VII.—Motor-generators of Van Depoele (1889) and Thomson (1887).

The upper figure, from a Van Depoele[17] patent of 1889, shows a double secondary armature *J J'* adapted to produce two-phase currents.

[16] No. 367,469, of Aug. 2, 1887.
[17] No. 417,654, of Dec. 17, 1889.

The figures of Plate VIII are from two patents issued to Henry[18] in 1894. The two armatures of the lower figure are directly connected by a piece of flexible shafting (3).

When two separate machines, a motor and a generator, are connected together so that the former drives the latter,

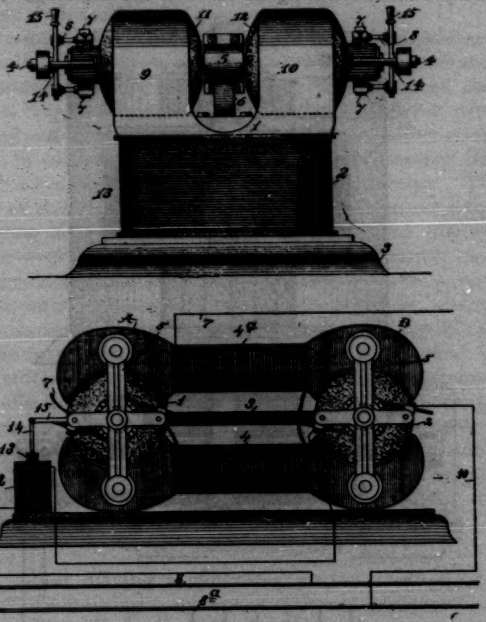


PLATE VIII.—Henry's motor-generators. 1894.

there is no inherent difficulty as to regulation; for each machine may be separately compounded, the one to yield a constant speed at constant pressure, the other *vice versa*, in the same way as if they were wholly independent. It is

[18] Nos. 512,820 of Jan. 16, 1894, and 524,852, of Aug. 21, 1894.

sometimes desirable, however, in such a case, to have all the regulation performed by one machine or by one circuit, which may be in this case either the primary or the secondary, this being chiefly a matter of preference, as the currents in both rise and fall together. Plate IX, which is from a

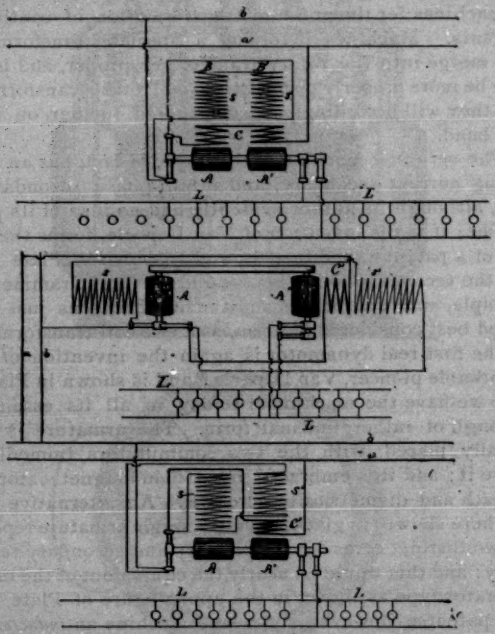


PLATE IX.—Rice's method of regulation for motor-generators. 1883.

patent to Rice[19] of 1883, shows three such couples, in each of which all the exciting current is taken from the primary circuit. In the upper couple, both fields are provided with compounding coils in series with the motor armature, one

[19] No. 495,229, of Apr. 11, 1883.

being arranged to decrease, the other to increase the field-strength in its respective field, according to well-known principles. In the lower couples, only the generator field is thus compounded.

DYNAMOTORS.

The proper signification of this word should be limited to machines for the pressure transformation of continuous currents. Machines involving a species transformation also merge into the rotary transformer proper, and in fact may be more properly termed "two-coil rotary transformers," and they will accordingly be considered further on under this head.

The very first machine of this type, in fact, has an alternating current secondary, and a four-phase secondary at that, although its author evidently had no idea of its possibilities; it is the invention of Van Depoele, forms the subject of a patent issued in 1882, and is shown in Plate XVI. But the secondary coil is not wound on the Gramme ring principle, and it is for this and the other reasons just mentioned best considered later on, as a two-coil transformer.

The first real dynamotor is again the invention of that remarkable pioneer, Van Depoele,[20] and is shown in Plate X. Here we have the machine of to-day in all its essentials, although of rather unusual form. The armature is horizontally placed, with the two commutators immediately above it; and it is embraced by a field-magnet extending beneath and diametrically across it. An alternative form (not here shown) is given, having a single armature replaced by two distinct cores for the primary and secondary respectively; and this would be nearly the equivalent of the motor-generator type as shown in the upper figure of Plate VIII. The patentee, however, styles this machine an *inductorium;* whence, as well as from his other patents of the latter class to which the machine bears a close resemblance, we are led to the inference that it is the latter which is the real ancestor of the dynamotor, and not the motor-generator, as might fairly be presumed to be the case from its somewhat more

[20] From his patent, No. 298,431, of May 13, 1884.

similar general appearance; while, at the same time, in its electrical properties also it is allied more nearly to the inductorium type.

The common continuous dynamotor is too simple and

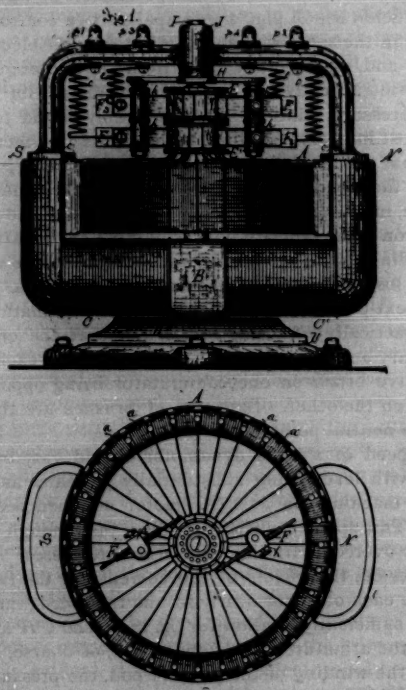


PLATE X.—Van Depoele's dynamotor. 1884.

well known a machine to require any special description; it has followed the same lines of improvement as other closed-coil dynamo-electrical machinery, and its improvements have been improvements in design rather than in the

introduction of any new principle. At the same time, however, it is a new machine, and possesses some peculiarities of its own, which will here be briefly touched upon.

The dynamotor is clearly distinguished from the inductorium on the one hand by the possession of strong and massive fields which play a principal part in controlling its motions, in the same way as in other dynamo-electric machinery; and, on the other hand, from the motor-generator in being intrinsically but one machine instead of two, so that its pressure relations are unalterably bound together.

Its most important feature, then, is this just mentioned, to wit, that the ratio of the primary and secondary pressures is wholly independent both of its speed and excitation, being the same, in fact (in the ordinary type, in which the amount of core-iron is the same for both windings), as the ratio of the two windings (with proper allowance for armature winding and core losses), just as in stationary transformers.

The next point to be noticed is that the armature reaction is practically *nil*, owing to the fact that the effects of the primary and secondary currents neutralize each other, the positive brush on one commutator being opposite the negative on the other. Both sets of brushes are therefore set at the neutral point.

The speed of a good dynamotor should vary but very slightly with load, being substantially the same as that of the same machine run as a *DC* motor on open secondary circuit. This speed is such as to allow just enough current to pass to overcome friction and armature losses. As the load comes on, the effects of the currents in the two coils neutralize each other, or nearly so, and the speed diminishes only just sufficiently to allow for the increased C^2R and core losses in the armature. This speed will, of course, be governed by the winding of the primary coil, the pressure used and the field strength, in the same way as in any motor. In the design of dynamotors, the considerations which govern the selection of speed relate to the proportion of iron and copper in the armature, corresponding precisely with frequency in the alternating-current transformer.

The question of regulation is the most important that in-

ventors and designers have been called on to meet in this machine. As changing the field-excitation can only produce an alteration in speed, without affecting the pressure relation, it is clear that where the magnetic circuits of the two coils are identical, we must look in another direction. In this case, supposing the primary to be supplied with current at a constant potential, whenever a large load is brought upon the secondary circuit there will be an undesirable drop in pressure at the secondary terminals of the machine, owing to the increased armature losses. Now, it is desirable not simply to compound the machine to compensate for this drop, but also to overcompound it to allow for line-drop, in the same manner as in the case of ordinary generators.

A device adapted to partly accomplish this end—though actually intended to maintain the adjustment of the brushes constant under varying load without sparking—is that shown in the upper left-hand figure of Plate XI.[21] As heretofore noted, the neutralization of the armature reactions by the two coils is not exact, due to the losses of conversion, which necessitate a proportionately increased motor current, and this uncompensated reaction increases with the load, causing some variation in the position of the neutral point, and consequent sparking. Now, by winding the *motor* coils over an additional length of armature core, not embraced by the generator coils, the counter-electromotive force is so increased as (the speed increasing in proportion) to increase the generator E.M.F. and current sufficiently to compensate for the drop, and at the same time bring the armature reactions of the two coils to exact equality.

The equality will be maintained at all loads, as the additional power gained is proportional to the primary current, and it is evident that a similar effect would be produced upon the pressure regulation, although imperfectly. In the other figures of the same plate,[22] however, we see a true pressure regulator, in which either or both of the two coils are provided with separate supplementary cores and inde-

[21] From a patent to Walter, No. 351,544, of October 26, 1886.

[22] From a patent to Thomson, No. 459,423, of September 15, 1891.

pendent series-wound field magnets acting upon each core. In the lower figure on the right, it is the motor-coil which has a series-wound field; on the left, the generator or secondary coil; and in the upper right-hand figure, each has a separate supplementary field.

Another method, which may be considered the electrical equivalent of the foregoing, is to arrange a small booster,

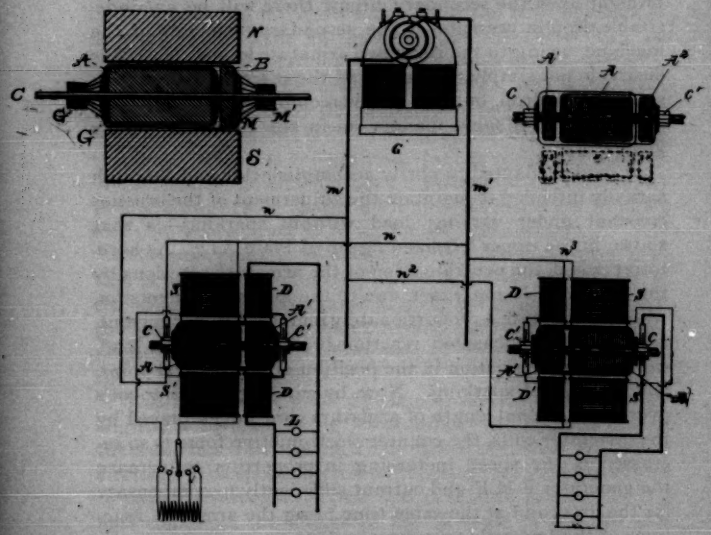


PLATE XI.—Compound dynamotors of Walter (1886) and Thomson (1891).

or series-wound dynamo in series with the secondary coil on the same shaft. A variation of this is shown in a patent to Burke,[25] issued in 1894, the booster being in series with the *motor* or primary coils, and excited by shunt primary and series secondary field windings, so as to increase the speed of the machine as the load increases. There are, however, serious practical objections to such a plan, for, as is

[25] No. 524,376, of August 19, 1894.

well known, such booster machines, which have to carry a very large current at a low pressure, are both costly and inefficient, and by thus introducing a second machine we lose all the advantage we gained from the consolidation of the motor-generator into *one* machine, introduce additional complexity, and at the same time do not regain the independence and flexibility of the motor-generator system. Moreover, as the dynamotor, besides supplying current, has to furnish the necessary power to drive the booster, the armature reactions are no longer balanced; and a larger machine must be used for this additional power.

Of armature-windings not much need be said, the main object to be kept in view being, here as in stationary transformer windings, the avoidance of magnetic leakage between the two circuits. The windings may be either side by side in alternate strips, or one over the other; the latter of which is deemed preferable in most cases, especially where toothed armatures are employed; but the presence of a high pressure coil may dictate a less desirable arrangement.

There is one species of dynamotor which deserves a special notice, which is that adapted to mediate between constant pressure and constant current circuits. All the machines so far treated of are intended only for constant pressure working, and are not fitted to perform this function, although it seems not unlikely they might be used to satisfaction between two constant current circuits—if such a case ever occurred in practice. The practical utility of a machine for the service just mentioned, however, arises wherever, for instance, we wish to obtain an incandescent-lamp from an arc-lamp circuit, or the reverse. In particular, it has been proposed[34] to operate scattered lighting circuits by individual motor-generators whose primaries are connected in series on a constant current circuit. An example of a dynamotor for this service is shown in the upper figures of Plate XII, which are taken from a patent to Thury.[35] This machine is constructed on somewhat the

[34] *Electrician* (London), V. 24, p. 112.
[35] No. 567,424, of Sept. 8, 1896.

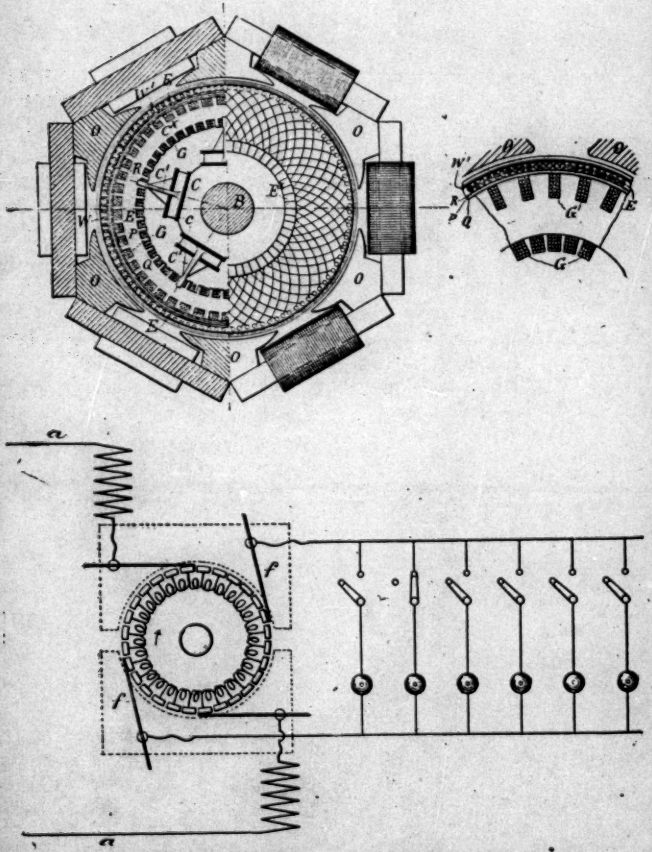


PLATE XII.—Constant-current to constant-pressure transformation.
1. Thury's method. 2. Scribner's method. 1896.

same principle as the constant-current stationary transformer—to wit, of large inductance and magnetic leakage between the primary and secondary circuits. The figure shows a six-pole machine having a ring armature core C^x, toothed on both its exterior and interior circumferences. In these grooves are wound, Gramme fashion, the coils G intended for connection with the constant current circuit. Over these is placed circumferentially a layer of insulation Q, over this a magnetic shield consisting of a layer of iron wires P, then another layer of insulation R, and finally the constant pressure coils E drum-wound over the insulation R. The large leakage and self-induction of the constant current coil enables the brushes to be shifted over the commutator without causing sparking, so as to be adjusted to the proper pressure called for by the load on the machine, which shifting is done automatically by means of a fly-ball or solenoid governor.

Another interesting machine for this purpose is that shown in the lower figure of the same plate, from a patent to Scribner.[26] This belongs perhaps more strictly to the rotary transformer than to the dynamotor class, as it has an armature of only one coil. It has two pairs of brushes, one, the generator or constant-pressure pair f, being fixed in the usual position on the commutator. The other, or primary pair, supply constant current to drive the machine, normally have a certain lead over the secondary pair, and are shifted automatically by a solenoid governor back and forth upon the commutator to keep the current constant, and in accordance with the voltage demanded to maintain the proper speed. When moved back, the current in the secondary circuit is increased, but is limited to that of the primary. The armature is thus divided into four portions, in two of which the current is greater and in two less than half the primary current, leading to armature reactions of a varying character, so that it would seem doubtful if the objection of excessive sparking could be successfully overcome.

Among "freak" machines we may mention one in pass-

[26] No. 574,278, of Dec. 29, 1896.

ing, described by Dieckmann[77] in a patent of 1894, and shown in Plate XIII. This machine shows a three-ring armature, the outer rings of which, *D d*, are wound with primary, and the central ring *F* with secondary coils. This central ring is composed of *non*-magnetic material, as wood. A double set of field-magnets *B B* is provided, one for each primary, and each set being wholly independent of the other. The magnetic circuit of the primary rings would

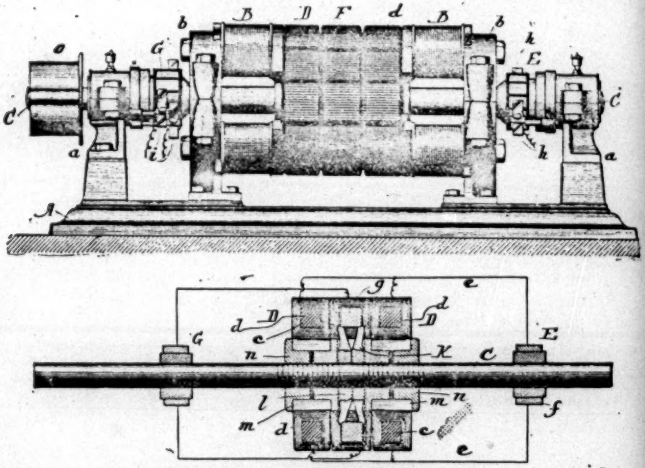


PLATE XIII.—Dieckmann's dynamotor. 1894.

appear to be largely completed through the field magnets *B*, but a portion of the induced field must pass through the secondary armature ring *F*. This ring is removed from the magnetic field created by the pole-pieces, and inductively influenced by the successive changes of direction of the current in the juxtaposed primary coils. The brushes on the secondary commutator are separated by only one commutator segment, and unidirectional impulses are thus

[77] No. 513,459, of Jan. 23, 1894.

transmitted to a lamp-circuit; there being a pair of such brushes opposite each pole-piece *B*, connected to as many secondary circuits. For equal primary and secondary windings, the primary volts of this machine would appear to bear a very high ratio to the secondary.

[*To be continued.*]

BOOK NOTICES.

A Hand-Book of Industrial Organic Chemistry. By Samuel P. Sadtler, Ph.D., F.C.S., Professor of Chemistry in the Philadelphia College of Pharmacy. Third edition, revised. 8vo, 529 pages and index. Philadelphia: J. B. Lippincott Company. 1900.

The third edition of this well-known and useful work finds it much enlarged. The rapidity with which all departments of chemistry, and especially applied organic chemistry, develop, makes very laborious the task of keeping such a book up to date. The author has done this duty well, and the present edition will maintain and extend the popularity of the work. We note from the preface that the most extended revision has been in the section devoted to dye-stuffs, among which are to be noted the tables for the identification of commercial colors. Such systematic methods are very useful to the practicing analyst who encounters often the problem of determining the nature of colors used in foods and beverages.

The elaborate bibliography appended to each section will be of great assistance to the practical analyst. The abundant statistical information will be interesting to many.

The work is well written and well printed. The illustrations are numerous and satisfactory, and there is a good index. H. L.

Commercial Organic Analysis. By Alfred H. Allen, F.I.C., F.C.S. Third edition. Rewritten and enlarged; revised and edited by J. Merritt Matthews, Ph.D., Professor of Chemistry and Dyeing in the Philadelphia Textile School. 8vo, 573 pages and index. Philadelphia: P. Blakiston's Son & Co., 1900.

The issue of this volume has been awaited for some time with much anxiety, for the earlier editions are out of print and the topics covered by them are of great importance to chemists. The chapter on aromatic acids, which formed the first sixty pages or so in the second edition, has been transferred to the third part of Vol. II (in preparation), and the present work opens with a chapter on tannins. Dr. Matthews has added much new material, especially, as might be expected, in the fast-growing department of artificial colors. A modern classification of these has been introduced and the details of descriptions have been condensed and made more rapidly available by the extensive use of tabulation. About eighty pages are devoted to the tannins, all the recognized methods of analysis having been included, but

the reviser expresses regret that the department of analysis is still in an unsatisfactory state.

The reviser's practical experience with color work ensures the trustworthiness of the section on colors. A glance at the index shows the great number of those now known. Rational formulæ are usually given. A short chapter on the chemical character of writing inks will be found interesting and valuable. We regret that Dr. Matthews has adopted the plan of giving journal references by the volume instead of by the year. The latter method seems more simple and direct. The index is extensive and creditable. H. L.

Machinists' and Draughtsmen's Hand-Book. By Peder Lobben, Mechanical Engineer, etc. New York: D. Van Nostrand Co. 1900. 8vo, pp. 438. (Price, $2.50.)

The author has designed this book to serve the needs of the great body of working mechanics and draughtsmen. It contains a large collection of tables, rules and formulæ covering a great variety of subjects. Many examples are given explaining the application of the rules and formulæ. It should prove useful to the class for which it is intended, not only as a handy reference book, but also as a text-book, from the study of which the reader may familiarize himself with the principles of elementary mathematics and mechanics. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, February 20, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 20, 1901.

MR. A. E. OUTERBRIDGE, JR., in the chair.

Present, 107 members and visitors.

Additions to membership since last report, 32.

Prof. M. I. Pupin, of Columbia University, New York, presented an address on "Electrical Wave Propagation," elucidating the principles involved in the study of these phenomena, with special reference to their application in his recent inventions in the field of long-distance telephony. The speaker illustrated his address with the aid of mechanical devices, exhibiting various modifications of wave transmission.

The subject was freely discussed. The paper and discussion thereon have been reserved for publication.

A vote of thanks was given the speaker for the interesting and very lucid manner in which he had treated his theme.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, January 2, 1901. Concluded.*]

The following reports were adopted:

(No. 2154.) *Improvement in Light-Projecting Glass.*—American Prismatic Light Co., Philadelphia.

ABSTRACT.—The light-projecting glass referred to in this application is protected by letters-patent of the United States No. 637,145, November 14, 1899, granted to George Moffat and Edward J. Dobbins, of Philadelphia.

The object of the improvement is to increase the amount of light that passes into a room and to secure equal distribution of same by diffusion. The glass used in this system is formed of parallel lens bars on one side, and parallel prism bars placed at right angles to the lens bars, on the other side.

The function of the external lens-bars is to refract the light in a horizontal direction and especially to make use of lateral rays that strike at so great an angle that they would be almost entirely reflected from a plane surface. The form of these lenses is such that there is no internal reflection from the inner surfaces of the prisms, thus securing the emission of all rays that strike these surfaces.

The function of the internal prism forms is to refract the light in a vertical direction, which, combined with the horizontal refraction of the external lenses, produces nearly uniform distribution in the room.

The forms of the prism faces vary to suit the requirements of distribution, and the angle from which the incident light comes. In extreme cases, where the light comes from a great elevation, as from the exposed sky over the top of a building or the like, the glass is set in a frame that is hinged from the top, and thus can be adjusted at any angle.

The investigators find that the combination of prisms on one side and lens bars at right angles on the other increases the strength of the glass and permits of panels of larger size being used. Also, the cylindrical form of the outer surface (placed vertically) renders it easy to clean the glass.

The report concludes: "On account of the special combination of scientific principles involved, and the excellent results obtained in places where this glass has been applied," the award of the John Scott Legacy Medal and Premium is recommended to the inventors. [*Sub-Committee.*—George A. Hoadley, Chairman; Geo. F. Stradling, Samuel Sartain, F. E. Ives.]

(No. 2163.) *Reaction Breakwater.*—Lewis M. Haupt, Philadelphia. The Elliott Cresson award is made. Report is reserved for publication in full. [*Sub-Committee.*—Ambrose E. Lehmann, Chairman; L. E. Levy, John Haug.]

The following passed first reading:

(No. 2141.) *General Electric Co.'s Constant Current Arc-Light Transformer.*

(No. 2162.) *Improvement in Gate Valves.*—Henry J. Schmitt.

[*Abstract of proceedings of the stated meeting of February 6, 1901.*]

The following reports were adopted:

(No. 2141.) *General Electric Company's Constant Current Transformer.*—General Electric Company, Schenectady, N. Y.

This report is reserved for full publication. The John Scott Legacy Medal and Premium is recommended to Elihu Thomson, the inventor. [*Sub-Committee.*—Francis Head, Chairman; Geo. A. Hoadley, T. Carpenter Smith.]

(No. 2162.) *Improvement in Gate Valves.*—Henry J. Schmitt.

ABSTRACT.—This invention is the subject of letters-patent of the United States No. 604,592, May 24, 1898, issued to applicant.

The valve consists of a carrier or cage which is moved by the thread on the spindle, or by a vertical movement of the spindles. The carrier is guided by a side projection which travels in a groove on the body of the valve. This carrier holds the valve disks, which are of brass, each having two lugs which project within the carrier and bear against the top and bottom, so causing them to move with the carrier. The projecting lugs are of such length that they bear against the disk on the opposite side, and, being rounded, permit the disks to make a good joint on one side, even if there be scale under the other. These disks are entirely free to move in a horizontal direction relative to the carrier, or to rock one over the other to allow the disk to conform to the plane of the seat. Vertically the disks must move with the carrier, and the first movement frees the valve on one side, but as long as there is a higher pressure on one side than on the others, one of the disks will be forced against the seat. This friction will be present in all classes of gate valves in some form or other.

The report concludes as follows:

"This valve is a marked improvement on the old form of Nelson valve, in that it is simpler and cheaper, and appears to be more effective. The Edward Longstreth Medal of Merit is awarded to the inventor." [*Sub-Committee.*—Arthur M. Greene, Jr., Chairman; J. Y. McConnell, Henry F. Colvin, Frank P. Brown, Chas. Day.]

First reading:

(No. 2140.) *Pneumatic Clock.*—A. L. Hahl, Chicago.

(No. 2160.) *Rivett-Dock Thread Tool.*—Herman Dock, Philadelphia.

(No. 2168.) *Bardwell Votometer.*—The Bardwell Votometer Company, New York.

(Nos. 2108, 2121, 2126.) *Various Grate Bar Inventions.*—Dismissed for want of data.

W. H. W.,
Secretary.

SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, January 24th. Dr. W. J. Williams in the chair.

Present, 45 members and visitors.

The following officers were elected to serve for the year 1901, viz.:

President—Dr. W. J. Williams.

Vice-Presidents—Lyman F. Kebler and Joseph Richards.
Secretary—W. E. Ridenour.
Conservator—Dr. Wahl.

Dr. Williams presented, as the annual address of the President, a paper entitled "A Brief Sketch of the Essential Requisites of Powder as Distinguished from Explosives." The paper was illustrated by the exhibition of an instructive series of specimens. The paper was referred for publication.

Mr. Lyman F. Kebler made a communication on "Walnut Oil." He had found on examination that numerous commercial products sold under this name were sophisticated. One specimen examined, for example, proved to be nothing else than glycerine flavored with certain essential oils, and quite unfit for the uses for which the genuine oil is so highly valued (*i. e.*, its eminent drying quality). Other commercial samples were found to be equally sophisticated. A specimen of the genuine oil, expressed from the kernel of the black walnut, was shown, and its drying quality was demonstrated by the exhibition of several samples of rubber-like oxidized films of the oil that had been spread upon glass.

Dr. H. F. Keller, Dr. R. H. Bradbury and Dr. S. P. Sadtler followed with a series of chemical lecture experiments, all of which were interesting and many novel.

A vote of thanks was passed to the contributors of the evening and the meeting adjourned.

W. E. RIDENOUR,
Secretary.

PHYSICAL SECTION.—*Stated Meeting*, Wednesday, January 23d, 8 P.M. Dr. A. E. Kennelly in the chair.

Present, 18 members.

The following officers were elected to serve for the year 1901:

President—Dr. Geo. F. Stradling.
Vice-Presidents—Prof. Luigi D'Auria, Prof. Edward A. Partridge.
Secretary—Jesse Pawling, Jr.
Conservator—Dr. Wahl.

Dr. Kennelly delivered the address of the retiring President, choosing for his theme "Some of the Present Aspects of Physical Science." At the conclusion of his remarks he alluded to the urgent need in the United States of a national bureau for the standardization of instruments of precision, such as those at the Kew Observatory, in England, and at Berlin in Germany. He alluded to the fact that there was at present pending before Congress a bill providing for the establishment of a bureau of this character, and urged that the Section should signify its approval of the measure. On Mr. Bradbury's motion, the Section signified its approval of the pending bill to establish a bureau of weights and measures, and urged its speedy passage. Dr. George F. Stradling presented a communication on "Recent Investigations of the Physics of Water," giving a *résumé* of a number of recent investigations of the subject which go far towards explaining a number of the anomalous physical properties of water.

W.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, February 7, 1901. Dr. Chas. F. Himes in the chair. Present, 28 members and visitors.

An amendment to the by-laws was adopted, providing for an Executive Committee to take general charge of the affairs of the Section. The President appointed as members of this committee, Dr. Henry Leffmann, Chairman, and Messrs. W. N. Jennings, F. E. Ives and John G. Baker.

Dr. Himes made some remarks on the permanency of photographic plates and papers, and in illustration of his remarks showed pictures made from plates that had been kept for sixteen years before exposure.

Dr. Leffmann contributed some observations on the "Effect of Light on Chemicals, especially Mercurous Compounds."

Mr. E. Wager Smith, of Philadelphia, exhibited and explained a new and ingenious "Exposure Slide."

The President announced that at the March meeting of the Section the subject of "Photographic Record Work" would be taken up.

F. M. SAWYER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, February 13, 1901. Prof. F. L. Garrison in the chair. Present, 17 members and visitors.

Mr. Joseph Richards gave the concluding portion of his address on the "Utilization of the Wastes from the Use of the White Metals." This was devoted especially to the recovery of the wastes from the stereotyping, electrotyping, type manufacturing and other industries in which solders, type metal, stereotype metal, pewter, britannia and other white alloys were used. The speaker exhibited samples of the wastes and the useful products obtained from them.

Mr. Richards exhibited a balance of his invention devised for the purpose of quickly ascertaining the proportion of tin in by-products containing this metal alloyed with lead and with antimony.

The paper is reserved for publication.

Mr. Caspar Wistar Haines read a communication on the "Earthquake of Colima, January 19, 1900," which was illustrated by a number of lantern views of the region adjacent to the volcano of Colima which was affected by the earthquake, and views of the buildings destroyed and injured. Reserved for publication.

Adjourned.

G. H. CLAMER,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, February 14th. Mr. John F. Rowland, Jr., in the chair. Present, 26 members and visitors.

The paper of the evening was read by Mr. Oberlin Smith, Bridgeton, N. J. The subject was "The Jig Habit in America." The speaker treated of jigs and their uses. The subject was discussed by Mr. Falkenau and others.

The paper is referred for publication in full.

DANIEL EPPELSHEIMER, JR.,
Secretary.